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DEVOTED TO

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(Stated meeting held Thursday, December 13th, 1906.)

The Art of Manufacture of Railway Car Axles.

BY HENRIK V. VON Z. LOSS, M.E.,

M. Am. Soc. M. E. Member of the Institute.

Mr. Chairman and Members of the Institute:

It was my good fortune to have been associated with the birth of the steel car, once an experiment, which quickly, however, became a standard. As the Consulting Mechanical Engineer of the Pressed Steel Car Company, I designed practically all of their plants as well as assisted materially in developing the different details of car construction. I had the pleasure of presenting this work to the railway profession of the world at a meeting of the International Railway Congress, held in Paris in 1900. The increase from the old 60,000 or

highest 80,000 lbs. car capacity to one of 55 tons suggested the necessity of having to overcome another difficulty that was encountered, namely, the weakness of the flange in the present cast-iron wheel. In a lecture delivered in February, 1904, I had the honor of laying before this Institute my work in that field. The solid forged and rolled steel wheel, which at that time was a mere experiment, is now a standard adopted by several of our leading trunk lines, one of these having only a few months ago placed an order for 70,000 wheels of this type. With the car and its wheels thoroughly strengthened and modernized, it occurred to me that the one remaining vital detail, viz: the axle, had a right to some consideration.

With the car axle the case is somewhat different from that presented by the car wheel. The old cast-iron wheel was decidedly too weak and the substitution of steel-tired ones was too expensive. Both facts had to be met and solved. The present axles, of course, do break, but not to the same extent as the present cast-iron wheels. However, when considering the required long life of a car axle and the comparative short period—about six to seven years—since the introduction of the 55-ton capacity steel car, we must admit that old statistics must be revised before we can with any reliability tabulate the total fractures of axles, which we from now on shall have to face. On this account I always felt that an axle somewhat stronger than the present standard should be the coming type. But secondly, and mainly, the method of manufacture as now in vogue is decidedly unfinished and crude, involving large wastes, both in material and labor. In order to more fully appreciate the present condition of this art, both as to method pursued and quality produced, I shall describe more in detail the manner used in the making of the standard axle of to-day.

A square billet, with about 7″ to 8″ sides, coming as a product of the blooming or billet mill, is the shape in which the metal reaches the axle shop. There it is heated and afterwards placed under a hammer, having generally a crew of three men and one boy, where the horizontally split semicircular dies are attached to the anvil block and to the ram. Three sets of dies are generally placed side by side, but in one block, roughing and finishing dies, the latter consisting of a pair of tapering and a pair of journaling dies, and the time consumed by the

hammering process varies with the size of product, averaging during a day's run, about fifteen minutes for a $5\frac{1}{2}''$ x $10''$ journal axle, this dimension being the one used for a 55-tons capacity car. After the hammering does come or should come the annealing process, not always indulged in, however: then the straightening, now very often omitted with the large axles on account of their great resistance. The next step is the cutting off the rough ends in separate machines, followed by the drilling of the ends or centering, so as to enable the turning lathes to receive them, and here they are now rough-turned, or brought down to sizes, leaving only about 1-16″ to be taken off in the finishing lathes at journals, dust guard seats and wheel fits, and in which machines the journals are also polished.

When in forging steel the material is rapidly finished from a high working heat, the grain remains coarse and open with impaired ductility and resisting strength. Hence, it is desirable to continue the forging process until the temperature of the piece falls below 1200° F. The structure of the metal and its endurance under working stresses are much improved by a final heat treatment or annealing. This is accomplished by uniformly reheating the finished forging after it has cooled sufficiently (certainly below 1200° F.) up to a temperature of 1500 to 1800° F.,—the higher temperature having proved the most effective, and then cooling down uniformly.

With the above in view the matter of annealing axles becomes of considerable importance and, while only occasionally specified, this step in the process should not be omitted if a high-grade product is desired. The annealing can be economically accomplished by rolling the axles through a continuous furnace having a heated center, being somewhat similar to the furnace used in annealing glass. The rolling prevents the tendency to warp, which otherwise would occur if a bar is cooled unevenly on two sides, and the mechanical construction involved is the simple problem of slow rolling on a pair of cooling rails.

The manufacture of railway car axles represents a very considerable tonnage. During the year 1904, which was one of decidedly dull business activity, the railroads adding hardly any cars to their rolling stock, the total output in this country was about 90,000 tons, of which amount the United States Steel

Corporation furnished about 63,000 tons. The year 1905, on the other hand, was one of very great activity, the United States Steel Corporation alone furnishing 150,000 tons. Based upon the same ratio, the total product of the country should then have been about 225,000 tons of axles. The greater part of this product represents new rolling stock, the remainder being renewals of axles on old cars. Assuming three to four axles per ton, the above total would mean the building and refitting of from 150,000 to 200,000 railroad cars in one year.

The material used in car axles is steel, with an amount of carbon that has been considerably increased in later years. As an illustration, I herewith attach the chemical specification of the Penn. R. R. for their axles:—

Carbon	0.40	per cent.
Manganese, not above	0.50	"
Silicon	0.05	"
Phosphorus, not above	0.05	"
Sulphur, not above	0.04	"

This same road considers the axle to have failed chemically if the analysis of the borings give figures for the various constituents outside of the following limits:—

Carbon	below 0.33 or above 0.50	per cent.
Manganese	above 0.60	"
Phosphorus	above 0.07	"

The main physical test of an axle is that of the drop. The standard Penna. drop test involves the following essential parts:—

The points of supports on which the axle rests during the test must be three feet apart from center to center; the tup must weigh 1640 pounds; the anvil which is supported on springs must weigh 17,500 pounds; it must be free to move in a vertical direction; the springs on which it rests must be twelve in number of the kind described in P. R. R. specifications, and the radius of the supports and of the striking face on the tup in the direction of the axis of the axle, must be 5 inches. When an axle is tested it must be so placed in the machine that the tup will strike it midway between the ends, and it must be turned over after the first and third blows, and when required, after the fifth blow. After the first blow the deflection of the axle under test will be measured.

The different car axles used by this road are each and all required to stand at least five blows without rupture, with a height of drop varying from $28\frac{1}{2}$ feet up to 43 feet, showing deflections of from 6 to $7\frac{1}{4}$ inches after the first blow. Separate from the above, the new $5\frac{1}{2}'' \times 10''$ journal axle, which is used for the 55-ton steel cars, shall stand seven blows, with a 43-feet drop and a $4\frac{1}{2}$-inch limit of deflection after the first blow.

The above first-named axles will be rejected if, with the number of blows already stated, they rupture or fracture in any way or if the deflections exceed from 7 to $8\frac{1}{4}$ inches respectively. With a $5\frac{1}{2}'' \times 10''$ journal axle, the deflection must not exceed $5\frac{1}{2}$ inches after first blow.

Some railroads are satisfied with having their axles turned only on journals, dust guard seats and wheel fits, leaving the remainder as it comes from the hammer, while others, as for instance, the Pennsylvania, requires rough turning from end to end, with the subsequent finishing on wheel fits, dust guard seats and journals. I believe the Pennsylvania's method is correct, when considering the present crude manner of making an axle under the hammer. The rough forging leaves the product very much unbalanced. I have seen as much as half an inch or more cut off the radius of the axle on one side, with the tool but little more than touching on the other. There has also been an assertion made that the metal needs inspection fro mend to end, requiring turning to do so.

On the other hand if a car axle could be forged entirely smooth between wheel-seats with little or no expense, there is no doubt as to the value of the tough surface skin in withstanding the severe alternating stresses, and as to the necessity of rough turning for the sake of inspection, the general results with the railroads of the country do not seem to bear out that assertion, when considering that the vast majority of axles inspected, passed and successfully run are rough between the wheel-seats. While on this particular subject I shall quote the following from an address delivered a couple of years ago by Mr. J. L. Replogle, of the Cambria Steel Co., before the Western Railway Club in Chicago:

"During a controversy with an inspector of a prominent railroad which specifies rough turning all over, we suggested to him that he take two axles of the same heat, one being

rough-turned to $5\frac{7}{8}$ inches in center, the other being smooth forged to same dimension. These axles were subjected to the same treatment throughout and were then tested to breakage. The rough-turned axle stood 21 blows of a 1640-pound drop from 43 feet height, and the smooth forged one stood 78 blows, or almost four times as severe a test.

"Tensile tests cut from the two broken axles showed the same chemical and physical structure.

"Extensive tests made at another works by one of the leading railroads specifying this, show that in axles of the average carbon, the smooth forged axle will stand approximately 43 per cent. harder test than the rough-turned one. Rough-turning an axle makes it more susceptible to rust."

There are many objections to be raised to the present mode of manufacturing axles and I shall enumerate some of them:

1st. Hammering metal in open dies is a poor method of improving the material. Under each blow of the ram the metal will greatly squash or flow out sideways at each end of the die, leaving imperfect compression on the material. Again, especially with the heavy modern axles, there is only a chance of the hammer-blow reaching the center of the billet, and due to its continuous rotation in the dies while hammering, there is also a tendency towards piping.

2nd. The weakest place in an axle is close to the wheel-seat, as it is here where the maxima stress moments occur. It would be only right under such circumstances, to expect the maximum amount of work to have been placed upon the billet at this point. But the reverse is the fact. The greatest hammering is at the middle and center and the least at the wheel-seat, where the cross-dimensions are more nearly those of the original billet.

3rd. All axles should be annealed, but generally they are not. They also should be straightened so as to avoid waste in rough-turning, but as already mentioned, such is rarely done, especially with the large sizes.

4th. The method of hammering an axle is so crude that in order to produce a decent mechanical product, the waste through turning and in cutting off the ends, becomes very excessive. 15% is quite common, in fact, with axles of moderate sizes this figure is considered good practice.

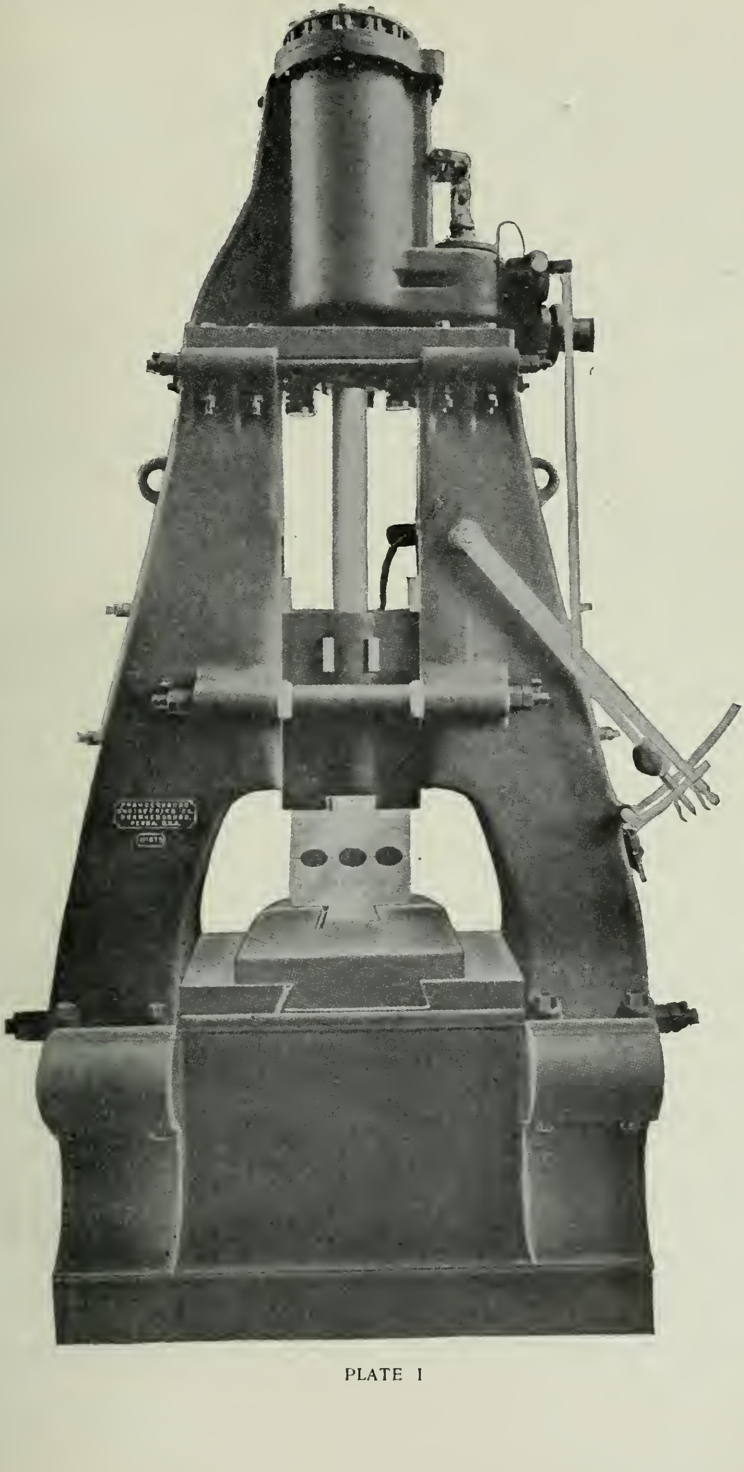


PLATE I

5th. Repairs to hammers is a great item, and the continuous breaking of piston rods is a worry which those of you who have been engaged in this art will thoroughly appreciate.

6th. A hammer is an expensive tool to use from a point of fuel. The latest hammers when operating on heavy axles average about 50 H. P. when in actual service and the steam consumption is one far in excess of what economic steam machinery should require.

I have tried to enumerate some of the most important objections to the present method of axle-making and it is but natural to assume that efforts have been made to overcome them. In order to insure more work on the metal, the Pencoyd Iron Co.—this company ceased the production of axles some years ago—increased the capacity of their hammers up to five tons and I believe six or seven is still better, while the prevailing custom is only from 4000 to 7000 lbs.

One of the leading axle works in the country has recently followed suit, but did not go far enough when doing so, their old hammers of 3500 lbs. capacity being lately followed by a few new ones of 7000 lbs.

Plate I represents a type of the modern hammers generally used in this art.

At some places the hammer has been superseded by the vertical forging press, which should mean a decrease in repair account, as well as in fuel cost, and it is very likely that it would give a product better in texture, and closer to dimensions, resulting in smaller waste.

In order to reduce the amount of work under the hammer, the Carnegie Company several years ago adopted an additional mill, which receives the square billets and breaks down its corners, producing practically an octagon billet to be sent to the hammer. I have been informed that this company has lately gone a step farther and introduced a mill, the product of which is a round bar. Of course, all and any of these processes require additional cost to be added to that of the original square billet, but they thoroughly show the appreciation of the necessity of having to do something. Nor must it be thought that this appreciation has not found an outlet in more radical ways. There are certain objections to the axle-hammering process which are fundamental, as for instance, the want of deep pene-

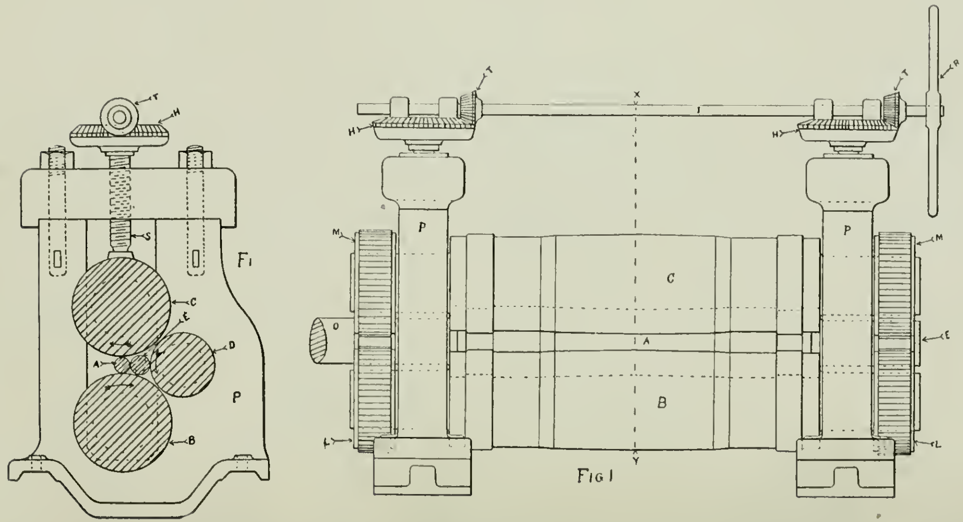


PLATE II

tration by the blow, the expending of a minimum amount of work at and near the wheel-seat, and the large amount of scrap, all of which when taken in connection with the additional cost necessitated by the introduction of extra mills for re-rolling the square billet, have brought about departures quite radical in their methods. First among them I shall mention the efforts to produce an axle by rolling machinery.

This principle has been the subject of many experiments for twenty or more years past and the method pursued was generally one of the following two:—

1st. End rolling, where a round bar is fed endways between a pair of rolls, the grooves of which are cut so as to form an axle in one or more passes, the circumference of each roll being equal to or more than the length of the axle.

2nd. Cross rolling, where the round bar is fed at one time throughout its entire length, into a pair of rolls, the axes of which are parallel to the axle.

The first method presents many practical difficulties, especially on account of the work in each pass having to be finished in one revolution of the rolls. It is more than likely that a hydraulically operated train would be quite preferable to an engine or belt-driven device because of the greater control of its movement. Due to several causes, the experiments proved a failure and the process was abandoned.

The second method has been tried possibly more extensively and I have witnessed some of the results obtained. A number of years ago a mill for this purpose was built at the Pencoyd Works under the patents of Mr. J. R. Jones. Plate II show the principle of the machine. Rolls B, C and D are driven, with roll E as an idler, this latter being supported throughout its entire length by roll D. A is the blank formed into an axle by grooves in rolls B, C and E.

The great objection to this method lies in the bad twisting effect upon the axle caused by the variation in the peripheral speed of each and all of the rolls, due to the different diameters, brought about by the cutting of the grooves. Mr. James Christie, whom we all know, devised then a mechanical scheme to overcome this great defect. It was never tried, however, and the process was afterwards abandoned. All rolling devices presented up to this time possess also in addition to the

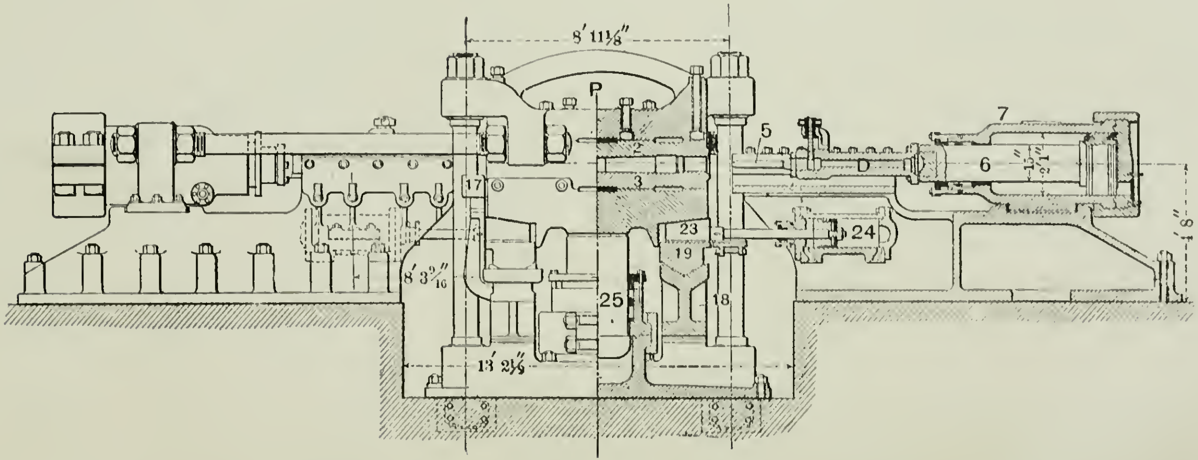


PLATE IV

objections found at the trials the feature, in common with the hammer process, of doing the greatest work on the blank near the middle and the least amount at the wheel-seats, a condition which properly should be reversed. They also require a blank of a circular cross-section.

We shall now consider the next step in the evolution of axle manufacture, viz:—"The Mercader Process."

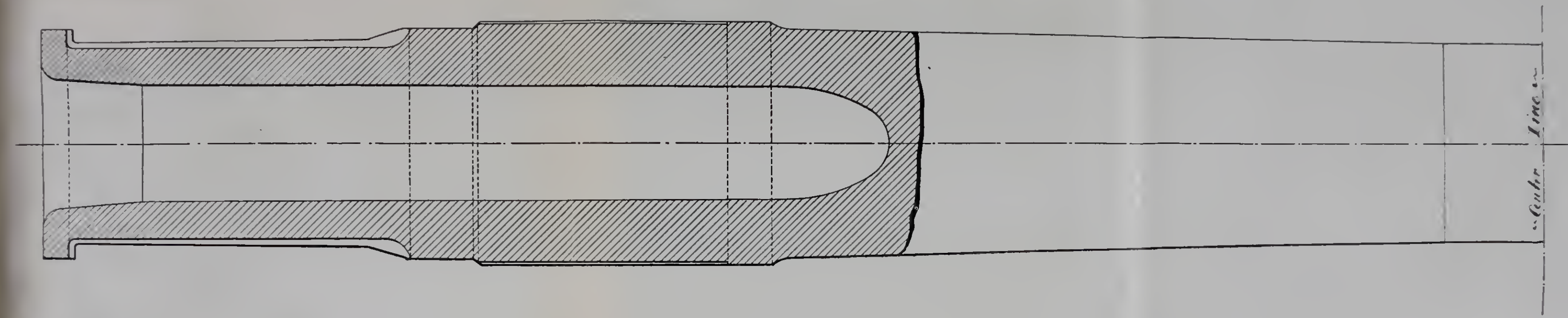
This method consists in placing a plain, round rolled bar of proper diameter and length in a longitudinally split die, the inner contour of which is that of the finished forging, with the die touching or slightly gripping the blank at its middle and ends. The half-dies are now fastened together, whereupon a long needle (equal to about one-third the length of the complete axle) is pushed against each end of the blank, penetrating it on the center line and forcing the metal sideways—and also slightly longitudinally—so as to completely fill the die, after which the two needles are withdrawn, the dies unlocked and the forging removed for end cutting, centering and turning. It is vital that the blank shall be perfectly straight before being perforated.

Plate III shows the blank and the forged as well as the finished product.

Plate IV shows a cross elevation of the axle press, partly outside view and partly in section. The punching needles, with their operating cylinders, are clearly shown. The die is split on a horizontal line, the upper half being stationary, while the lower half can be dropped and then moved horizontally out of the way for the introduction of the blank and removal of product.

Plates V, VI and VII show a number of these axles, some made and piled and other mounted on wheels.

The value of an axle forged in closed dies has been proved by a series of tests made by the Howard Axle Works in connection with this process and which were embodied in a paper read by Mr. Mercader before the British Iron and Steel Institute. The Pennsylvania Railroad specifications were followed in each instance and the axles were made under temperatures varying from 1500° F. up to 2000° F. Those made at the cooler temperature proved the strongest, requiring over seventy blows for fracture, while those



5½" × 10" Journal Mercader Axle.

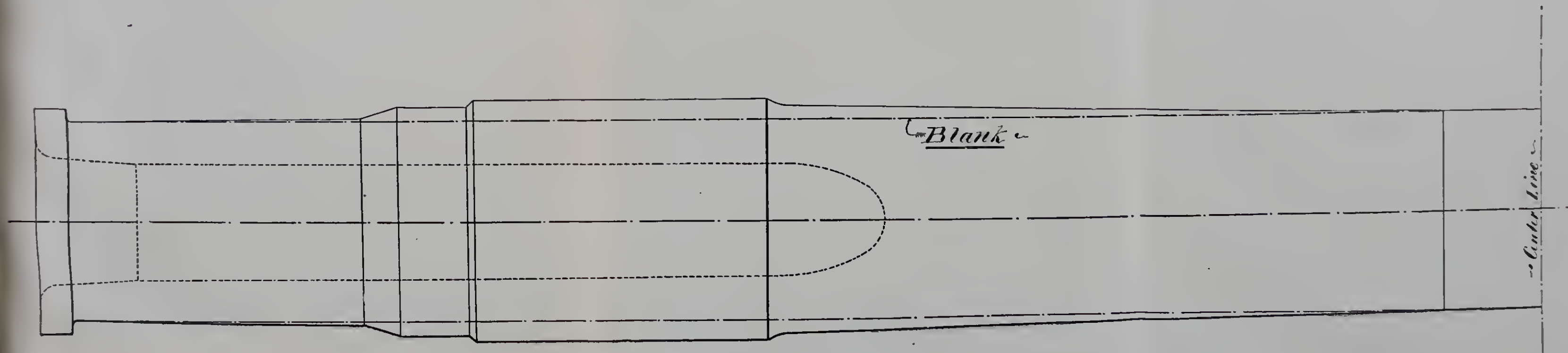


PLATE III

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PLATE V

made at the higher ones required about forty, but it must be added that this test was specially severe, the axle being turned over after each blow, instead of after every blow, as required by the specifications.

A number of these axles were made at the Howard Axle Works at Homestead and a few of them are to-day in service on the Pennsylvania Railroad. The process had several points in its favor:—

1st. It dispensed with the rough-turning, hence doing away with a large amount of scrap.

2nd. It saved the outer skin between wheel-seats, thus adding considerably to the strength of the product.

3rd. The axle was exposed to great pressure throughout its length and cross-section, due to being forged in closed dies, in this way producing a very dense and greatly superior metal.

4th. It was also claimed that by being hollow, the journals would run cooler and that the weight saved—the axle being solid only throughout its middle third—would be of some consideration.

On the other hand, there were some vital objections to its adoption:—

1st. It was found very difficult to guide the needle centrally.

2nd. It became necessary to insert a loose drop forged steel cap over the end of each needle, so as to permit their withdrawal and to prevent the welding together of needle and blank. The caps remained in the axle.

3rd. Due to the great length of the pushing needles, as compared to their diameter, about 9 to 1, there was considerable difficulty in securing punches that would stand the strain and the wear.

4th. Due to the light amount of flow of the steel, the blank had to be a finished round rolled bar. If originally rough, the product would remain rough. The cost of producing such a bar, instead of using an ordinary billet, was a tax on the process.

5th. The heated blank had to pass through a straightening machine before being placed in the axle press.

6th. Some railway officials raised objections to the axle on account of the large hole, $3\frac{1}{4}$ inches in diameter, which repre-

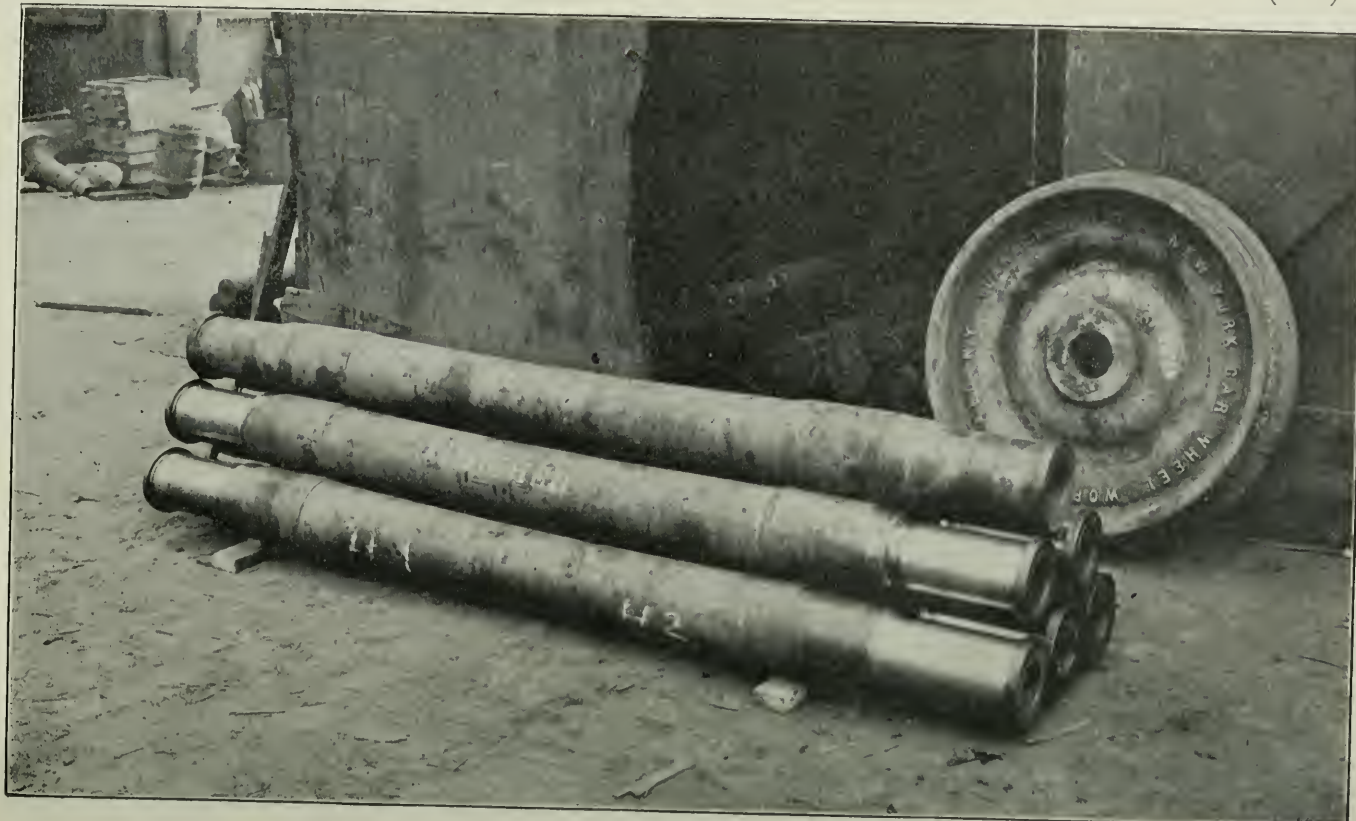

PLATE VI

sents over 20% of the theoretical strength of a $5\frac{1}{2}'' \times 10''$ journal. A smaller punch would not stand the strain, which again means that this process could not be adapted to any axle except the one just mentioned, which is that used on the 55-ton freight cars. It was also a question whether the parts joining the solid center and hollow ends were considered safe.

A number of the difficulties enumerated were overcome, some wholly and some in parts and again, others not at all. The result was the recent abandoning of the process, it having been found according to my informant that about 20% of the product had to be scrapped as unreliable. It remains, however, as an exceedingly interesting mechanical experiment in general, reflecting considerable credit upon the inventor, the late Mr. Mercader, and as the greatest effort up to that time to improve and cheapen the manufacture of axles.

The next step in the evolution of axle manufacture is one invented by myself. A number of years ago, while connected with the Pencoyd Iron Works, I designed an upsetting machine for bridge eye-bars, adopting in this connection a system of dies, which, generally speaking, may be considered to consist of a closed box, enveloping a stationary bar and arranged to move longitudinally against its free end. This machine, as well as a larger one—built later on the same lines—have been both successfully operated for years by the American Bridge Company, and as a result of my work in this direction, came the suggestion of embodying the upsetting principle to a billet with the view of producing an axle. Plates VIII, IX, X and XI show the machine intended for this purpose. It consists of a central stationary die, horizontally split, and two moving end dies similarly divided, each of which contains a cylindrical heading die, the latter possessing a slight longitudinal movement inside of its respective end die. The upper halves of the split dies are simultaneously lifted or lowered by being all suspended from an upper casting containing two hydraulic cylinders, the pistons of which are stationary and butting against a long top frame, which in turn at its ends is tied to the lower bed-plate by four heavy bolts. This lower bed forms the housing for the die-system. On each side or end of the housing are two horizontal, telescopic cylinders, the tiebolts of which are in part attached to the bed-plate. The main piston in each

PLATE VII

outside cylinder is attached to and operates each moving end die. It is, however, a cylinder in itself, the piston of which butts against the cylindrical heading die, above mentioned.

The dies being lifted, a billet cut to right length and weight is pushed into the machine sideways between the vertical bolts by a small manipulator, the dies closed and the main end cylinders opened to the water. This operation carries all the moving dies, including the header, towards the stationary center, the heading dies at present remaining inoperative with relation to the moving end dies. The entire system is stopped at the end of the stroke by an abutment on the stationary center die, allowing $\frac{1}{4}''$ as the thickness for the collar of the surplus metal at its narrow edge. Some distance before the stroke is finished this collar commences to form, as the sliding friction between metal and inside of dies, especially during the period of forming sharp corners, is so great that the material will rather flow sideways into the open space. A collar formed under such conditions would quickly stop the up-setting stroke and in order to overcome this difficulty, the adjoining ends of center and moving dies are provided with shears that undercut the collar, enabling the upsetting stroke to complete the work. The water is now permitted to enter the inside cylinders, whereby the outer axle collars are formed, allowing a place as shown for the surplus fin of material. The two inner or central pins must be cut off before the axle can be removed, as otherwise the product is locked in the dies. This is accomplished by the inside cylinders, automatically and simultaneously with the forming of the outer collars in the following manner:—Each half shearing-die has two bolts screwed into its front collar and is moved forward by the stroke of the inner ram, as shown in the plan view.

The stationary center shear is simultaneously yielding longitudinally by having its ears or side wings forced backwards by movable upper parts of the lower side guides, which again are operated by the inner rams through the main pull-back cross-head, as shown in plan view. The retirement of the center die sleeve, as just described, is made possible by the previous withdrawal of the middle wedge-shaped part.

The process of operation of the valve levers will hence be as follows:—

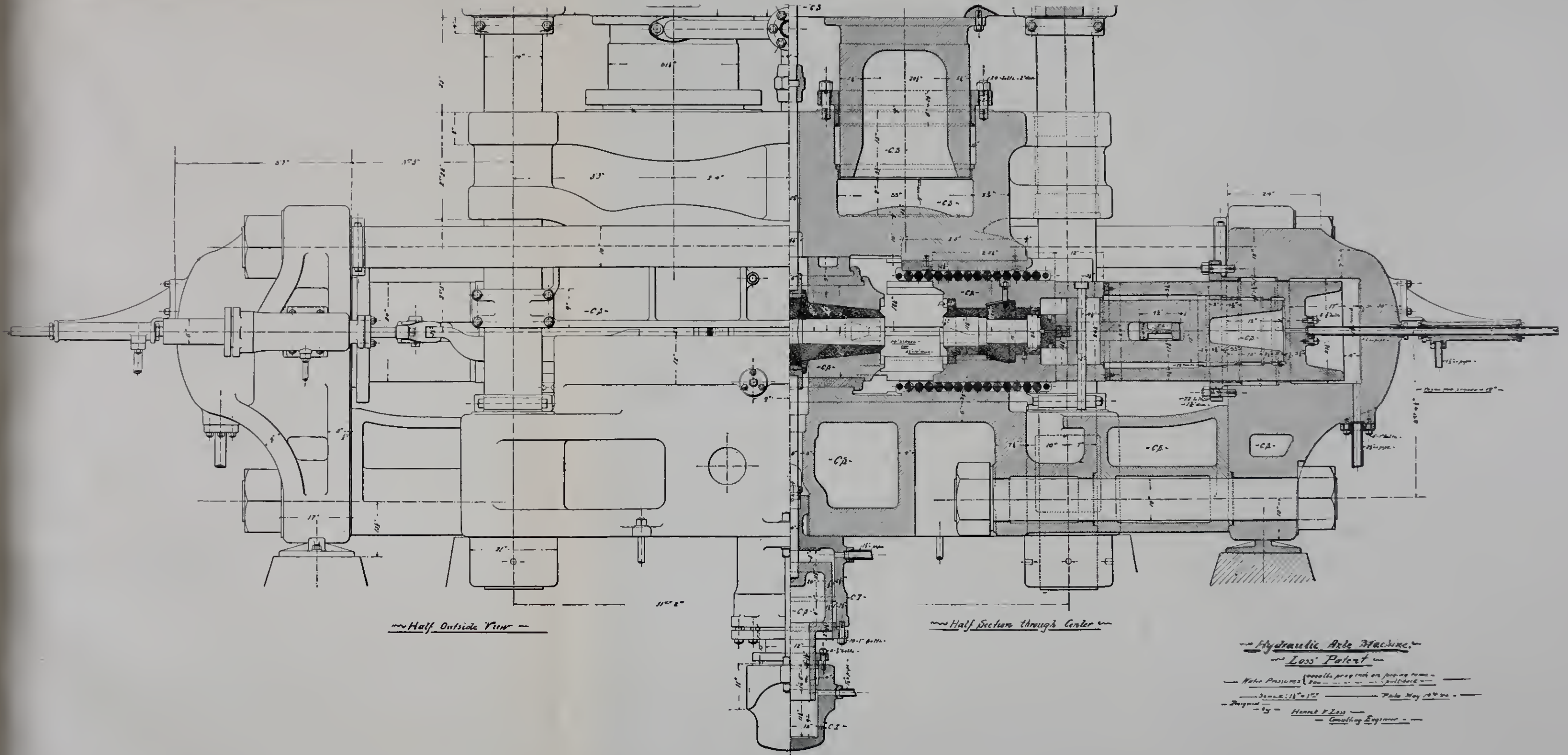

PLATE VIII. Lower part of front elevation

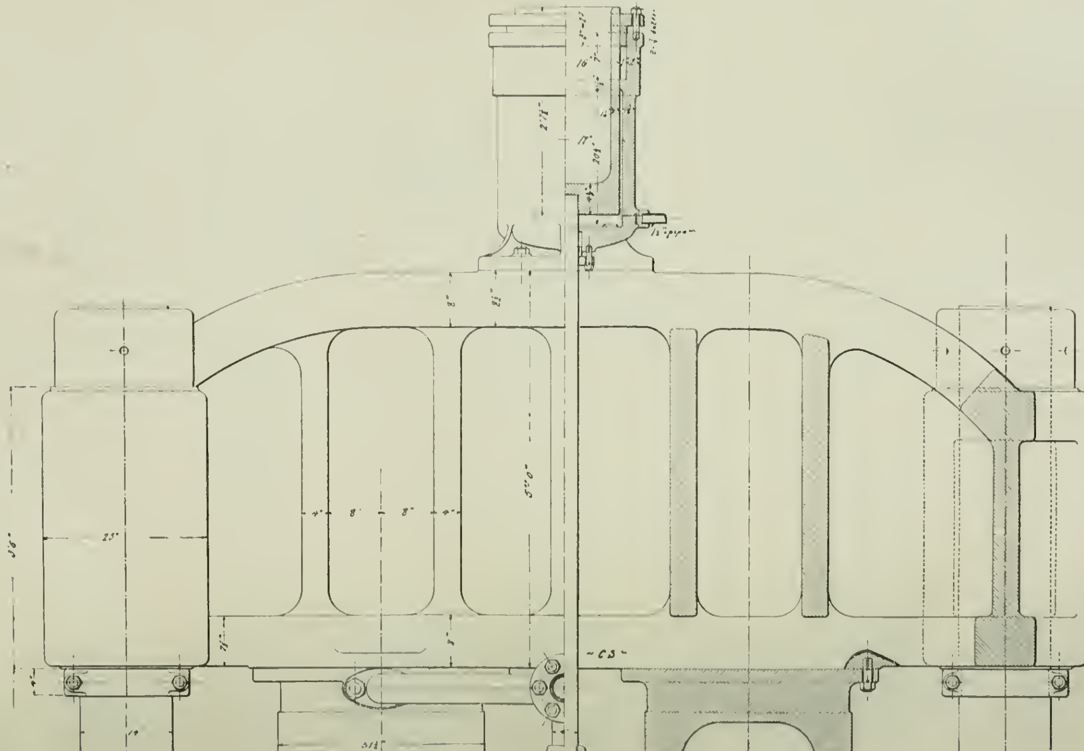

PLATE IX. Upper part of front elevation

1st. Close dies vertically by letting low pressure water on main rams, afterwards locking same or applying an intensifier.

2nd. Throw low and afterwards high pressure water on main horizontal rams.

3rd. When the moving dies stop, throw water on the top and bottom low pressure cylinders. This is done through one single valve lever. Also, if necessary, unlock or remove high pressure water from die closer.

4th. Throw high pressure water direct on inner rams.

5th. Reverse levers for horizontal rams and for the die-closer. The water on ram on top of machine will then lift the die-closer automatically.

The pull-back cylinders for the horizontal rams are located on each side of the main cylinder and have constant pressure, which is also the case with the lower of the two cylinders under the bottom of the machine. The pins connecting the moving guides to the pull-back cross-heads are made as breaking pieces in case any unusual cause should prevent the movable die lining in the middle stationary die from moving back under the pressure of the inner ram. As another precaution a breaking piece is attached to the end of this inner ram where it bears against the four bolts which operate the shear in the moving die

The capacity of the holding-down cylinders is 3500 tons, representing a pressure of 10,000 lbs. per square inch of the horizontal projection of a $5\frac{1}{2}'' \times 10''$ journal axle, a figure which is very ample in the light of the experience gained in upsetting eye-bars. The horizontal pressure is 1000 tons at each end, or over 50,000 lbs. per square inch of the cross-section of the largest axle used. This excessive figure will, of course, insure sharp corners on the product, as well as overcome the large fractional resistances inside the long dies.

The upsetting of a steel bar is simply a forging process, conducted in a longitudinal direction, and if properly performed, will similarly condense and refine the metal. Like any closed-die method, it is very superior to the use of a hammer for reasons as previously given.

In all longitudinal forging there is a tendency to buckle or bend and if the piece under treatment is not properly guided, excessive buckling will result in laps or laminæ that render the

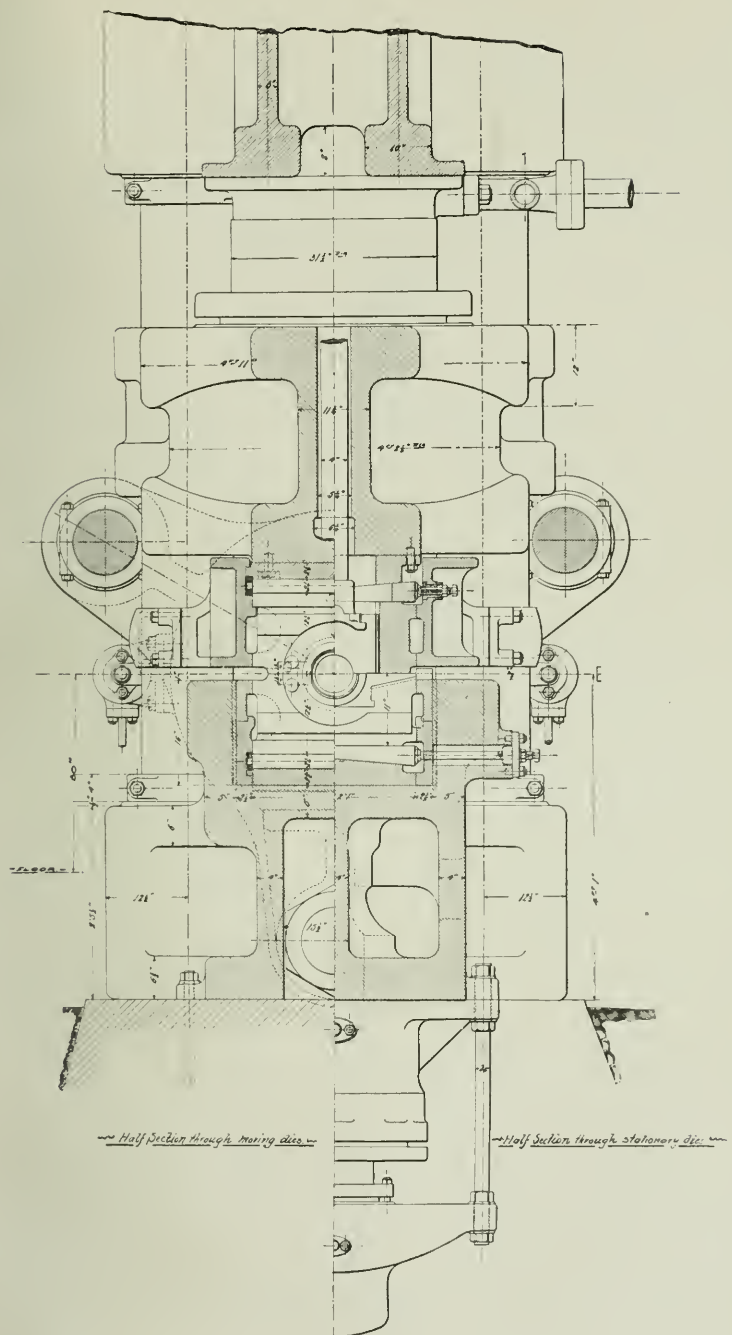

PLATE X End views

product useless. With iron, the upset portion needs considerable increase in area in order to equal the strength of the non-upset part, even if well guided during the process. The reason is simply the fact that as iron is not homogeneous, a longitudinal pressure with subsequent yielding will cause an intermingling of the so-called "fibres" or slag laminæ in a manner partly approaching the condition resulting from upsetting a bunch of wires. Homogeneous steel, however, acts quite differently.

With surface folds avoided, it matter not in which direction the metal is forced to flow. Eye-bars are upset to an extent of the new area being 150% in excess over the original one, while with an axle this increased percentage is only about 50 or 60. Hence if eye-bars are made without folding or buckling, no question of that kind can legitimately be raised against the axle, remembering that the billet is held or supported at its middle, where the moving dies will first fill. Referring again to the upsetting of eye-bars, the excess of material around the pin, as compared to the body of the bar, was 50 per cent. in the days of iron bridges, but with the substitution of steel, this figure has been cut down to from 20 to 25 per cent. and I have witnessed eye-bars with 6% excess break in the body when placed in the testing-machine. It must be understood that this excess of metal, whatever the percentage may be, is also intended to take care of the bending stresses existing on each side of the pin, and as these strains are naturally much more than 6 per cent. in excess of the plain bar tension, the test showed that the metal had in this case been improved by the upsetting process. In order to shed some light upon the problem as to the condition of upset steel, the American Bridge Company last year instituted a series of experiments at Pencoyd, all of which, however, were made on small sections, viz: $6'' \times 1\frac{5}{16}''$ bar and $2''$ round, the former being upset to a $14''$ diameter eye and the latter to a $2\frac{1}{2}''$ diameter for a length of $5\frac{1}{2}''$. I have heard the opinion entertained by some engineers, —inherited no doubt from the days of iron—that upsetting actually hurts the metal, and while the explanation already given as to the difference between iron and steel could not be contradicted, I was, nevertheless, pleased to secure a copy of the tests just mentioned. They establish thoroughly that no

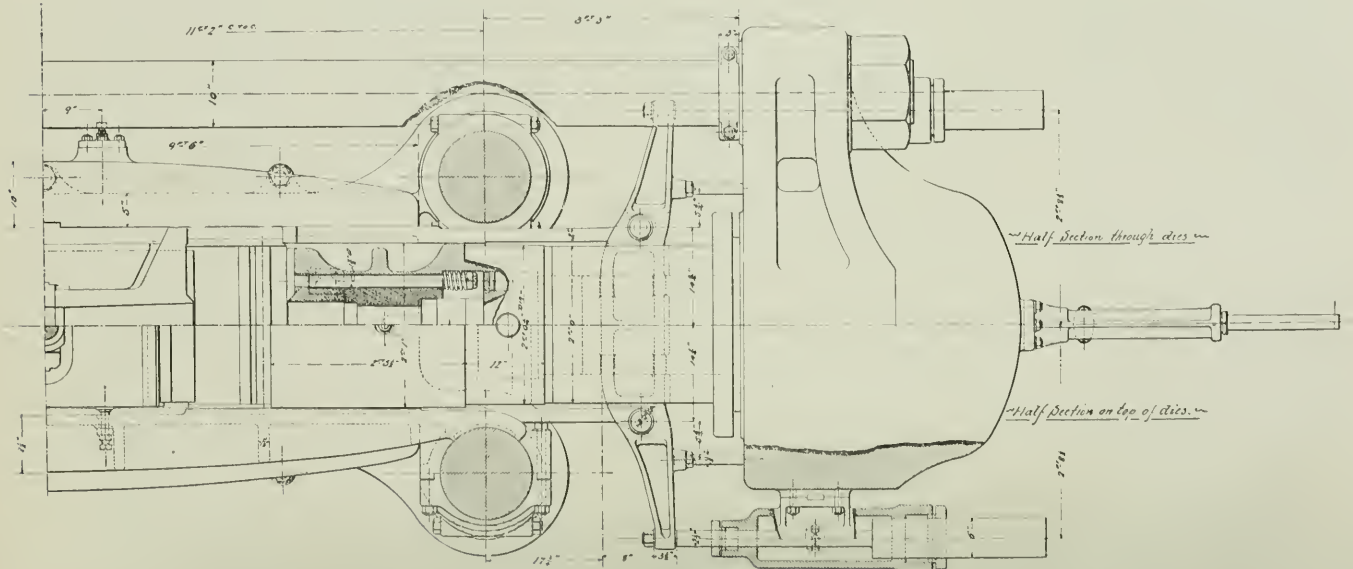

PLATE XI. Plan view

harm is done to the metal by the upsetting process and while the upset parts do not indicate any special superiority, it must be remembered that it could hardly be expected that a large ingot when rolled down to such small sections as a 2″ round, or 1 $\frac{5}{16}$″ thick bar should be improved by any subsequent mechanical manipulation. With a billet, however, the result would not only show no deterioration, but a decided improvement.

A resumé of the Pencoyd tests is as follows:—

Four pieces of the body of the rectangular bar when *turned* and threaded and pulled in the testing-machine showed elastic limits from 37,600 to 40,700 lbs. per square inch, with practically no variation between the annealed and unannealed portions. Their ultimates were from 67,700 to 67,900 lbs.

The upset head gave under similar conditions elastic limits from 37,800 to 42,250 lbs. per square inch with ultimates from 69,100 to 73,300 lbs. Other test-pieces of the same bar similarly taken, but of *square* cross-section, showed a slight decrease in strength of head instead of the increase above given for the round sections, registering an average ultimate of 69,000 lbs. per square inch for the head as against 71,000 for the bar. Here, therefore, the one result offsets the other and is, I dare say, merely a matter of speed of testing, heating, etc.

On the round 2″ bar upset to 2½″ at its end the elastic limits of the body varied from 33,000 to 39,000 lbs., the steel being softer in this case and the ultimates ranged from 57,640 to 61,350 lb. The upset ends gave elastic limits from 30,000 to 38,700 and ultimates of 56,200 to 61,100 lbs.

The summing up of the report by the Engineer of Tests is as follows:—

"Differences between body of bar and upset portions do not seem to be marked in any case."

The "Stahl und Eisen," of April 15th, 1905, contains a detailed statement covering two separate months' operation of a German axle plant. I have thought it of sufficient interest and importance to have this article translated, adopting also our money terms and weights, each ton being 2,000 pounds. The plant contained two steam hammers, one large for the body of the axle and a small one for the journal part.

FIRST MONTH.

Open Hearth Billets used as follows:—

34.65	Tons	at	$17.92 equals	$ 620.95		
210.206	"	at	16.84 equals	3540.00	Cost per ton of	
33.86	"	at	14.46 equals	489.60	finished axles.	
Total 278.716	"	at avg.	16.68 "	4650.55	$21.10	
Coal for heating blooms : 53.5 tons at $2.40					128.25	0.58
Coal for steam boilers : 68.00 " at 2.40					163.20	0.74
Wages paid for the month					317.00	1.44
Incidental expenses					71.40	0.32
Insurance per month					12.13	0.06
Depreciation of boilers					17.70	0.08
Total					$5360.23	24.32
Saleable scrap such as crop ends and chips (15%) : 41.97 tons at $11.84					497.18	2.25
Net output of rough turned axles 220.40 tons					$4863.95	22.07

NOTE:—

After hammering, but before being cropped and turned, the output weighs 262.27 tons, which means a loss in weight by scaling in furnace and at hammers of 16.44 tons or 6%.

The finished axles equal 79% of billets. Axles sell in Germany for $34.60 per net ton.

The output is worth $7625.84. Net profit per month equals $2763.82 or $12.54 per ton.

At four axles per ton average, the above output equals 882 axles or 37 axles per day.

SECOND MONTH.

		Cost per ton of finished axles.
166.16 tons of Basic O. H. Billets used at $16.84 per ton	$2793.13	$20.40
Coal for Steam Boilers 44.09 tons at $2.74	120.45	0.88
Coal for heating furnace 41.76 tons at $2.74	114.03	0.83
Wages paid for the month	232.12	1.69
Castings for repairing	22.85	0.17
Other materials used	191.75	1.40
General expense	74.76	0.54
Insurance	9.19	0.07
Depreciation of boilers	10.55	0.07
Total	$3573.83	26.05

Saleable scrap such as crop ends and chips (14.7%) 24.57 tons at $11.20	290.00	2.11
Net output of rough-turned axles 137.17 tons	$3283.83	$23.94

NOTE:—

After hammering, but before being cropped and turned the output weighs 161.74 tons, which means a loss in weight by scaling in the furnace and at the hammers equal to 4.42 tons or 2.60%.

The finished axles equal 82.5% of billets.

At 4 axles per ton average, the above output equals 550 axles or 23 axles per day.

Selling price equals $34.60 per net ton.

The output is worth $4746.00.

Net profit for the month equals $1463.00
" " per ton equals 10.60

CHEMICAL ANALYSIS OF AXLES.

Silicon	Phosphorus	Manganese	Carbon
1.07	0.08	0.78	0.17
1.03	0.092	1.38	0.18

Tensile strength	Elongation	Contraction
71262 lbs. per sq. in.	18%	28.1%
77236 " " " "	19%	36.0%

It is seen from the above that the saleable scrap, such as crop ends and chips, amounted to 15% in one month and 14.7% in another.

The article does not clearly state whether the product was rough-turned or finished, ready for the wheels. Unless an axle is shipped as a unit with its two wheels, it is nearly always rough-turned, the finishing being done at the place of assembling. In any event, the finishing cuts represent but a small, fractional part of the total scrap and might be ignored in a comparative estimate.

There is also to be observed the extreme softness of the material. Steel with .17 or .18 carbon has long ago been given up in this country for axle purposes.

In order to throw light upon the saving effected by the introduction of die-forged axles I collected some data covering output and costs in one of the larger axle hammer plants in the Pittsburg district. With die-forged product, I have been guided as to necessary labor and output by the results of the

two eye-bar upsetting plants now in existence. One boy is intended to work the press valves and another to operate the valves for the manipulator, which latter picks the billet up from a roller bed and carries it sideways between the uprights into the machine, where it is finally deposited in the dies. After the forging is completed, a similar manipulator on the other side of the press removes the forged axle. One man will look after the process generally and grease the dies. It is believed that these three workmen will suffice for the operation of the machine proper, with an output that is only limited by the ability to cool the dies, which will be done by sprays of water.

COMPARISON IN COST OF THE MANUFACTURE OF RAILWAY CAR AXLES BY HAMMER AND BY PRESS.

Forging by Hammer:		
One Hammer—3 men and 1 boy—$1.75 per hour		
Average 5 axles per hour; wages for hammering	35c.	per axle
One Press—One man and 2 boys—90c. per hour.		
Average 20 axles per hour; wages for pressing	4½c.	"
Saving in wages per axle	.30	
" " cutting ends and centering	.15	
" " turning per axle	.15	
" " straightening	.05	
Total per axle	.65	
Averaging 3 axles per ton, which covers the present heavy freight cars, this saving becomes	1.95	per ton
Saving in repairs to hammers and to other machinery	.15	" "
Saving in fuel, based upon 50 horse-power, as the average work of the hammer	.15	" "
Total per ton	2.25	
Scrap:		
Minimum amount saved per axle, 70 lbs. or about 200 lbs. per ton = 10%. (German test during two months' run gave 15%).		
Difference between prices of axles and scrap 1¼c. per lb.		
Saving through scrap	2.50	per ton
Total saving per ton	$4.75	

Including everything, it should be perfectly safe to count a saving of $5.00 per ton over the best modern practice, a figure

which with a low-priced product, as this is, would warrant the scrapping of any present plant in existence.

Taking the process as a whole, a summing up of its facts and merits may be stated as follows:—

1st. Work on the metal—When forging an axle by hammer, the outside fibres or parts receive more work than the centers or inner ones. When upsetting it, however, the inner parts are shortened just as much as the outer ones and hence the flow at the center is just about as great as at the surface.

2nd. Work on the metal—In the ordinary method of forging an axle under the hammer, the main work is done on the middle part and a minimum at and near the wheel-seats. With the upsetting process these conditions are reversed,—the wheel fit and adjoining parts receiving the greatest amount of forging as they properly should do, these regions being the most liable ones to breakage.

3rd. Repair account—This item becomes very excessive with hammers, while with a well-designed press it is practically nothing barring wear of die-sleeves.

4th. Labor—Four hammers require twelve men and four boys, while one press being the equivalent can be run by one man and two pulpit boys.

5th. Fuel—Instead of the wasteful process of a steam hammer, the single stroke hydraulic process, when operated on the intensifier principle, means a considerable saving at the boilers.

6th. Turning—The axle when made is true and smooth throughout. Less allowance needs hence be made for turning of wheel fit and journal and then again between the wheel fits; the surface being true and smooth, the material is better off by having the hard outer scale remain intact. Hence no rough-turning.

7th. Straightening—The entire die system for both ends are planed units, well guided in housings, that take in the entire length of the axle, and hence the product must be straight when removed from the dies. If the axles are run directly from the upsetting machine down an inclined track through a continuous furnace, a hot axle entering at one end while a cold or cool one is leaving the other, there would be no danger of the axle again curving and the straightening process can be eliminated.

8th. Centering—The centering and cutting-off operations are omitted, as the axle can be upset to length and the heading die fitted with a tit which will center the axle while upsetting it.

9th. Cost of installation—An upsetting machine with all intensifiers and a complete valve system will cost about $30,000. Add $10,000 for piping, foundations and dies, the total becomes about $40,000, if low pressure water is available. The latest hammers at one of the leading axle works cost about $8,000 apiece. For the same amount of production we shall need about four hammers, which, with their expensive foundations, would involve a cost of at least $40,000, assuming steam to be had, this figure equalling the expense of one complete press. Likewise is saved cost of axle lathes and of the centering and cutting-off machinery.

10th. Capacity—The actual time to make an axle will be from 3 to 5 seconds, but the real time will, of course, include the removal of axle and the insertion of blank. With proper arrangements for removing the finished article from one side of the press and for the feeding of the blank on the other, two minutes would be ample for the process. Certainly one machine will be able to make twenty axles an hour, allowing a safe average and also considering time necessary for cooling the dies.

11th. Scrap—From sixty to ninety pounds of scrap is saved per axle. This figure includes the material removed by rough-turning and by cutting off the ends. At times this figure reaches 100 to 110 ℔s.

12th. The blank or billet can be octagonal if desired; it needs not be round. It is not smooth rolled, but it is essentially a *billet* and not a *rolled bar*.

I have had made a model in hard wood at $\frac{1}{8}$ scale, which is shown here to-night. A number of axles have been upset on it, the material operated upon being that used in the manufacture of picture frame mouldings and consists mainly of linseed oil, white lead, glue and some sugar or molasses, this mixture being also accepted by the United States Patent Office as a guide to its decisions regarding flow of metal. Some of the product of the model is also here to-night for your inspection

and shows clearly the flow of the material with its different fins and offsets.

Mr. Chairman and members of the Institute, I thank you very much for the interest shown and the attention given me this evening.

STRENGTH OF GRIND-STONES—WET AND DRY.

Tests seem to indicate that the strength of a grind-stone is considerably reduced when it is wet. The wetting not only decreases the tensile strength of the material, but it adds weight and thus augments the centrifugal pull at a given peripheral speed. The reduction of strength appears to be as much as 40 or 50 per cent. A dry section of stone broke under a stress of 146 lbs. per square inch. Another section of the same stone, soaked over night in water, broke at 80 lbs. A better stone, under the same conditions, broke under stresses of 186 lbs. per square inch when dry and 116 lbs. when wet. Much difference of opinion prevails as to the maximum safe allowable speed at which to operate the stones. Some grinders use a peripheral speed as high as 4500 feet per minute, while others limit it to 2500 feet. Little difference is observed in the liability to breakage, this leading to the conclusion that a frequent cause of breakage must be hidden in flaws or cracks, which would permit the disruption of the stones at the lower speeds.—*Iron Age.*

PRODUCTION OF IRON ORE IN 1905.

The production of iron ores in 1905 in the United States amounted to 42,526,133 long tons, as compared with 27,644,330 long tons in 1904, with 35,019,308 long tons in 1903, and with 35,554,135 long tons in 1902, a gain in 1905 over 1904 of 14,881,803 long tons, or about 54 per cent. The value at the mines of the ore mined in 1905 was $75,165,604, a gain as compared with the 1904 value, $43,186,741, of $31,978,863, or 74 per cent. As in the six preceeding years, the production of iron ores in the United States in 1905 was never equalled by that of any other country.

PRODUCTION OF COPPER IN 1905.

The production of copper increased from 812,537,267 pounds, valued at $105,629,845 in 1904, to 901,907,843 pounds, valued at $139,705,716 in 1905, an increase of 89,370, 576 pounds in quantity and of $34,165,871 in value.

ELECTRICAL SECTION.

(Stated Meeting, held Thursday, November 22d, 1906,)

Independent Telephone Development.

By James B. Hoge.

President of the International Independent Telephone Association of America, Cleveland, Ohio.

Considered from the standpoint of practical utility and convenience, the telephone is the greatest invention of this progressive and inventive age. It may be justly claimed that its adoption marks an epoch in human progress, since its use has done more for all practical purposes to annihilate time and distance than any other method of communication or transportation. Few perhaps think of the telephone in connection with transportation, yet to-day it is doing very much to make travel in many instances unnecessary. Stop a moment and consider how much more crowded the streets of your city would be if it was not for the use of the telephone. "Don't travel—telephone," is a sound maxim that is being very generally observed.

I ask your pardon for digressing a few moments to call attention to what seems to be an inherent human instinct, the desire for rapid means of communication. We see it manifested even among savage peoples, and explorers tell us of a unique plan in use by the tribes of certain hill countries. A messenger is dispatched to the top of the nearest hill and shouts his message, using a code of whoops and yells, to the next messenger, who transmits it in like manner from the next hill top, and so on. By this means, we are told, the tribes could communicate very rapidly with each other. The American Indians at the time this country was discovered had a well developed

system of smoke signals, which enabled them to transmit intelligence regarding the movements of their enemies or any important matter in a very brief space of time. Numerous methods were employed by the early settlers for communication between centers of population; we find the slow going messenger wending his way over hill and dale, the lumbering stage coach, making its way over the old National pike, and other post roads, with a few passengers and heavy mail pouches, with relays of horses and drivers, covering at best from forty to sixty miles a day; the more rapid pony rider mail carrier, often averaging 100 miles a day. Then there was the wigwag system, seldom, if ever, used in civil life, but employed in military circles. Then the steam railway, a wonderful improvement over the stage coach, reaching at first, in a limited way, the principal centers of population over circuitous routes, with heavy grades and crude construction, but passing from improvement to improvement and developing into the wonderful railway system of to-day that makes possible our Twentieth Century Limiteds, traveling palaces, rushing across the country with their precious human freight, conveying the United States mail from this city to Chicago, a distance of 825 miles, in 16 hours.

Now, as a crowning achievement in methods of communication, we have the telephone, which, like all other electrical inventions, was made possible by the one whom you have seen fit to honor by naming your institute after, who with his kite discovered that wonderful, mysterious fluid we call electricity, leaving its great power, its varied applications, as a problem for future generations to utilize for their profit and pleasure. Truly the citizens of the civilized world owe to Benjamin Franklin a debt of gratitude which will carry his name down to future ages as a benefactor of mankind. Far seeing as he was, he could scarcely have imagined the extensive use of his discovery, the wonderful inventions and progress in which it would result, and could he revisit this city to-night, he would not believe that it was his discovery that made possible the beautiful lights upon your streets and in this auditorium, the power that moves your street cars, that operates your telegraph instruments, and that beneath your streets are thousands of miles of copper wire, over which conversations are be-

ing carried on between parties located many miles apart, as clearly and distinctly as though the speakers were in the same room. This indeed is a wonderful age and the telephone is not the least of its wonders.

To return to our subject, the first public record of a device for the transmission of speech over an electric conductor appeared on August 18th, 1854, in a magazine published in Paris, known as the "Illustrated Universal Journal," giving an account of a crude apparatus constructed by Charles Boursel, a soldier in the African army, who had attracted attention by delivering a course of mathematical lectures to his comrades in a garrison in Algiers in 1848. Boursel, in describing and explaining his apparatus, made the startling announcement that "The spoken word in Vienna could be instantly transmitted by electricity to Paris." Nothing is on record to show that Boursel made any practical use of his invention, but in 1861, Philip Reis, a teacher in a boys' school in Fredericksdorf, near Hamburg, Germany, came before the public with an apparatus with which he claimed he was "enabled to reproduce the tones of various instruments and even to a certain extent of the human voice." Reis called his invention the telephone, the name by which it has since been known. He also manufactured and sold the apparatus in a limited way. As early as 1860, Daniel Drawbaugh, of Eberly's Mills, Pa., a little town of half a thousand inhabitants, about ten miles southwest of Harrisburg, in the Cumberland Valley, was endeavoring by experiments with the primitive appliances within his reach, to convey vocal sounds over an electric wire. There is nothing to indicate that he ever heard of Boursel or Reis, but between 1867 and 1869 he succeeded in constructing an apparatus consisting mainly of a glass tumbler, a tin cup and a mustard can, connected through a membrane, by means of a wire leading from a battery, with another instrument placed some distance away, over which he was able to transmit vocal sounds of a certain range. The device was crude, and Drawbaugh was not sufficiently skilled to comprehend or explain the scientific principles involved.

On February 14th, 1876, two petitions were filed in the United States Patent Office, making application for a patent on the telephone, each describing it as an invention for "trans-

mitting vocal sounds telegraphically." One was a formal application by Alexander Graham Bell, of Massachusetts, the other a caveat on the part of Elisha Gray, of Illinois. It was a coincidence without parallel in the history of the Patent Office, as both covered practically the same ground, and involved the same points. However, the patent was granted to Bell, on March 7th, less than a month after the application had been made. One of the first instruments manufactured was exhibited at the Philadelphia Centennial that year.

Immediately after the patent had been granted, the Bell Telephone Company was organized under the laws of the State of Massachusetts. Later the Western Union Telegraph Company secured control of Gray's device, with improvements thereon by Edison, and started in the business of installing and operating telephone exchanges in direct competition with the Bell Telephone Company. The latter realizing that their anticipated monopoly was in serious danger lost no time in ridding themselves of competition. A deal was promptly made with the Western Union, then suits were brought against all of the Bell's other competitors to enjoin them permanently from using telephone apparatus. This case reached the United States Supreme Court in 1888, and was heard before seven Judges, four favoring the Bell Company and three dissenting. The dissenting members of the Court based their opinion on their belief in the priority of the invention of Daniel Drawbaugh of this State.

The Bell Company, being put in possession of the controlling patents by the United States Supreme Court, and having made their arrangements with the Western Union to keep out of the field, apparently felt there was nothing further to fear from competition. Accordingly they continued the business policy which they had inaugurated, charging exorbitant rates and restricting the service, preferring to do a small business at high prices to popularizing the service at reasonable rates. The treatment of patrons, as might be expected from a gigantic corporation having such a complete monopoly, was arbitrary in the extreme.

The telephone business of the country continued with this policy of management until the patents expired in 1894. In December of that year, there were 291,253 complete tele-

phones installed in the United States, or approximately one for every 240 persons. By this time, the public had become so thoroughly aroused over the fact that they were prohibited from enjoying what seemed to them a wonderful convenience, if not an absolute necessity, that people from all walks of life in every community were ready to go into the business, not so much with a view of financial gain as for the purpose of securing the telephone service they needed. The Bell management felt certain that the invention of Emile Berliner, whose patents they had purchased and which were filed in the Patent Office June 4, 1877, but not issued until November 17th, 1891, would prolong the monopoly of the business until at least 1908; so when competition was threatened, every officer of an Independent company, as well as every subscriber to an Independent telephone, received a notice from the Bell Telephone Company that they were infringing patent No. 463,569 of Emile Berliner, which the Bell owned, and that they would be held responsible for infringement and damages. Nor was this an idle threat; in nearly every instance previous to 1888, upon the rendering of decisions favorable to the Bell, Independent companies were driven out of business and their equipment reduced to scrap and burnt, widespread publicity being given to such cases as a warning to other foolhardy investors, who might dare to invade the field of the Bell monopoly. It required courage in those days to engage in the Independent telephone business, when the investors faced the prospect of being prosecuted for infringement, and having their property confiscated and destroyed. Yet courage and faith were not lacking among the pioneers of the industry, and the present extensive system is a monument to their daring and perseverance.

Feeling the hopelessness of fighting the Bell single-handed, some of the prominent men in the Independent movement invited representatives of all the known companies in the United States to come together in Detroit, Michigan, on June 22nd, 1897, for the purpose of forming an organization for mutual protection. This organization was effected, and a substantial sum subscribed to defray the expenses of fighting the patent cases through the Supreme Court of the United States, if

necessary. One after another these cases were carried through and won by the Independent interests.

Telephone apparatus at the time the patents expired in 1894 was very crude, the service was slow and transmission unsatisfactory. To supply the widespread demand for apparatus, Independent manufacturing companies started up almost immediately, improvements were made on the apparatus, competition between the different interests put all on their mettle, and more was accomplished between 1896 and 1900 in the way of improving the apparatus and service, and extending the use of the telephone, than had been done in twenty years previous. Prior to 1896, a telephone in the country was a decided novelty; to-day it is so common as to attract no special attention. After establishing themselves in the smaller cities, the Independents extended their lines out into the country, reaching all the post offices in a county; then the farmers began to organize companies and build, bringing their lines into the different post office centers where exchanges were installed, each county becoming a net work of wires. This service has been constantly increasing, finances for its development being in most cases furnished locally, until to-day there is over three hundred million dollars invested in Independent telephone properties, with more than three and a half million telephones installed and several hundred thousand miles of long distance toll lines connecting the different exchanges. The people in many of the larger cities, where the Bell was furnishing telephone service, were slow to appreciate the advantages to be derived from competition. They realized very often that they were paying more than their service was worth, and that there was a great deal of room for improvement in both the service and treatment, but dreaded to burden themselves with two telephones, "the double telephone nuisance" as the Bell taught them to consider it. In many cases where the citizens were willing, in fact anxious to have an Independent exchange installed, they were prevented through the Bell's control of their chosen representatives, who sometimes placed their own pecuniary gain above the welfare of the people they were elected to serve. If this entire history was written up by Miss Tarbell or some of the other well known writers, who have made a specialty of corporate methods, it would prove

equally interesting and enlightening as the record of the Standard Oil Company or any of the other great trusts. One by one, however, the Independents have won their fights for entrance into the larger cities, the common sense of the citizens, when the real facts regarding telephone competition had been made clear to them, demanding Independent companies as the only means of securing justice in telephone rates and service.

Sometimes the Independent companies, in the early days, after obtaining franchises were unable to develop their property in the face of the greatly reduced rates, or even absolutely free service promptly offered by the Bell Company, and were forced to retire or sell out to the monopoly. Wherever this has happened, with scarcely an exception, another Independent Company has been formed, proper provisions being made to prevent a like occurrence. One or two examples may not be amiss. A few years ago an Independent plant was installed at Portland, Oregon, and forced the Bell to reduce its rates and improve service; it was not strong enough, however, to withstand the continued attacks of the Bell Company, backed by other corporations and political power in control, and finally sold out; rates were at once raised and service became unsatisfactory from an operating standpoint. On December 7th, 1904, an application for another Independent franchise was presented, and after a fight which brought the matter into politics, upon the petition of 10,000 voters the matter was submitted to a vote of the people the following June. The result was 12,213 votes for and 560 against the franchise. Evidently the citizens of Portland prefer competition to monopoly after having tried both. At South Bend, Indiana, the first Independent Company was forced to abandon the field, but its successor to-day has over 3,000 telephones in South Bend against about 900 of the Bell, although the rates of the latter are the lower at present. In the entire county the Independents have 5,000; the Bell about 1,000. Perhaps the South Bend people do not forget that it was not until competition was introduced that rates were lowered, and that when the first Independent Company had been removed from the field rates were promptly raised. No doubt they also appreciate that the present extensive development is due to competition, for under

monopoly the Bell had only 240 subscribers, and showed no disposition to extend its service.

On November 6th, the citizens of Omaha, Nebraska, at the regular election ratified an Independent franchise by a vote of 7,653 to 3,625. The Independent victory there marks the close of as fierce a fight as the Bell has ever made in any city of the country against the entrance of competition. For over three years this struggle has been going on, the Bell using every influence and sparing no expense in its efforts to retain its monopoly. There is a reason for its activity, for with Omaha added to the Independent list, the Bell's one claim to the toll service of the country surrounding it has disappeared, since in all of the territory tributary to Omaha the Independents outnumber the Bell. In Nebraska the Independents have approximately seventy-five thousand (75,000) telephones. In Iowa the Independents have over one hundred and eighty-five thousand (185,000), a total of two hundred and sixty thousand (260,000) in the two States; the Bell has only, approximately, eighty thousand (80,000) in the same territory. With Omaha built it will give the Independent Companies at least forty thousand (40,000) additional telephones in the two States in three years, and completes the system in that section.

At the November election, Denver, Colorado, also voted in favor of an Independent franchise. Last summer one was granted at San Francisco, and within the last ten days the Independents have been given a franchise at Milwaukee. These cities with Omaha are the only ones of special consequence, except Cincinnati and Chicago, west of the Ohio River, where the Independents are not strongly intrenched or building. In Chicago a franchise has already been granted and the Independent Company has over forty miles of tunnel under the city streets, this tunnel also being used for hauling freight. The telephone part of this property is controlled by a number of Chicago citizens and railway and telephone interests surrounding the city. It has lately been leased with all franchise rights to a syndicate of well known active Independent operators, who have completed their arrangements to see that it is fully developed, and Independent long distance connections given the numerous cities surrounding the metropolis, who have been clamoring vainly until now for such connections.

Speaking of the Bell Telephone Company, and its "iron grasp" upon the City of Chicago, Corporation Council Lewis said, "Here in this community there is no monopoly which has seized her more ruthlessly, which has ground her more oppressively, or which has more outraged or wronged her people than the telephone company." In the very near future this "ruthless," "grinding," "oppressive" monopoly will be once more forced to reckon with Independent competition, which there is no reason to doubt will bring the same relief to the citizens of Chicago as it has to those of other places.

In other lines of business, competition has been the life of trade; the telephone business has not proved an exception. When the electric light was invented, many of the (artificial) gas companies that had been charging from $3.00 to $4.00 per thousand cubic feet were inclined to believe that their business was ruined. Forced by necessity, they began to study their economies, and by marketing their by-products and the introduction of new devices for the use of fuel gas, they were enabled to develop a day and night load, as well as a winter and summer load, which made it possible for them to reduce the price of gas to an average of $1.00 per thousand cubic feet, bringing it into competition with coal for cooking and heating. To-day there is practically no limit to the amount of light and heat required in this country. So it is with the telephone; there is more business in this country to-day than both systems can properly take care of, and the more rapid their development, the greater will the demand become until every one desiring telephone service has been satisfied—and who can say whether that condition will ever be reached?

There are approximately 7,000,000 telephones connected with both the Independent and Bell exchanges in the United States. If the development throughout the country was as great as in some counties of the central States, it would require at least 14,000,000 telephones, twice the number at present installed. Without competition, there would be less than 2,000,000 telephones in the United States at present; equipment would be crude, rates high, the service unsatisfactory, and the management arbitrary. The small towns and the rural districts and millions of residents and small business men in our cities would be deprived of the greatest convenience

of modern times. Not only has competition as represented by the Independent companies offered lower rates, better service through the use of improved apparatus, more courteous treatment, and developed territory hitherto untouched, but it has forced the Bell to do likewise in sheer self-defence. While installing its own 3,500,000 Independent instruments, competition has compelled the Bell to increase in eleven years to ten times the number of telephones it had in service at the expiration of its more than seventeen years of absolute monopoly.

See what competition has done in your own city. Prior to 1900, when the Keystone Company secured their franchise, you are reported to have had approximately 10,000 telephones; to-day, six years later, you have approximately 70,000 telephones with a superior service and more reasonable rates. The experience in other cities is similar. Cleveland had less than 6,000 telephones when competition was started in 1900, and to-day there are approximately 50,000 telephones; business rates have been reduced from $120.00 to $72.00 per annum; residence rates reduced from $72.00 to $48.00, with party line residence rates as low as $24.00 per annum, thus bringing the telephone within reach of all the citizens. The same results have followed the introduction of competition in all of the cities of any size, while the smaller places and the rural districts were deprived of the service entirely until furnished by the Independents.

I should like to call your attention to the present situation in Canada, where the Independent movement is of very recent growth, and the business still largely a monopoly, conditions analogous to our own a few years ago. I think a study of the situation there will convince the most skeptical that the extensive development of the telephone in the United States is directly due to competition.

Recognizing the necessity for improvement in telephone conditions, the government of Manitoba appointed a select committee to inquire into and report regarding the various telephone systems. A similar committee had been previously appointed by the Dominion Government and had held its sittings in Ottawa; testimony taken before it filled two large volumes of an average of about one thousand pages each. The Manitoba committee, after making a thorough investigation of

its own, and carefully considering evidence presented before the Dominion Committee, reported to their Assembly. This body, after careful deliberation, decided to take the necessary steps to enable the Manitoba Government to construct and operate its own telephone system, and to petition the Canadian Parliament and the Crown to permit the expropriation of the Bell Telephone Company's plant and to refuse an extension to that company's capital. The Honorable Colin Campbell, Attorney General of Manitoba, in a speech before the Assembly, attributed the telephone legislation "To the growth of the Independent telephone companies in the United States, to the costly and limited service of the Bell Telephone Company, and the natural objection of the people of Canada to a monopoly."

The decision of the Committee, as set forth in its report and the debate with reference to the proposed legislation, was that the telephone is a necessary part of civilization, and is such a public utility that it should be operated to serve the people as a whole, and give to every one an opportunity to enjoy its advantages at the lowest cost. It was pointed out that the system of telephones can not be considered complete until every residence, including the farm house in convenient places, has been connected with every other; that the use of the telephone will continue to increase until it has been installed not only in every place of business, but in the home of every citizen. Special stress was laid upon the need of the telephone in the homes of farmers. It was urged that the present rates charged in Canada for telephone service are exorbitant and that a considerable reduction could be made; that the rural telephone system is absolutely neglected and discouraged at present; that the service of the Bell is unsatisfactory and too costly, and that no progress can be looked for from that corporation.

The League of Canadian Municipalities concurs in this view. In a letter to the Postmaster General of Canada, who conducted the inquiry held at Ottawa, the Secretary of the League, in setting forth the views of that body, says: "There is a very widespread conviction, based on what appears to be a solid ground of fact, that the Bell Company's rates are far higher than they ought to be. If my own inquiries into the matter are of any use, and I may say that I have followed it

without any prejudice, weighing many statements and much published matter on both sides, I consider that the progress of the use of the telephone as a home comfort among the mass of our people is immensely retarded by the present virtual monopoly."

In commenting on the progress of the Independent companies in the United States, the Committee reports that "everywhere the entrance of such companies into the field has resulted in the furnishing of satisfactory service at much lower rates than had previously obtained and in the immense extension of the use of the telephone. A noticeable feature of the telephone development in the United States was the large number of long distance lines and lines giving intercommunication in rural districts." The report further states "That it has been demonstrated to the Committee that long distance communications to the South may be easily obtained through the Independent telephone companies in the United States."

It goes on to show that the general result of competition in the United States has been an immense extension of the telephone in all directions, and especially to the farmer, and a great reduction in rates; that in many cases both 'phones could be rented for the price formerly paid for one, and that in places where the charge for both 'phones is higher than for one, it was inconsiderable and more than compensated for by the increased and improved service. Regarding the relative desirability of the single or dual systems, Attorney General Campbell says: "I agree that it is undesirable to have two companies if possible to obviate such conditions, but if we cannot get competition we cannot get a reduction of price, and if we can only get the benefit of competition for the people by entering into the operation of telephones, both as a province and as municipalities, I think we would be justified in so doing."

Among the evidence considered by the Committee were communications from business men regarding the actual working of telephone competition. The following is a summary of 1400 answers from 189 exchanges in the United States to five questions addressed by an American banker to leading business men at such places. This evidence is valuable, coming, as

it does, from our fellow-citizens who are users of the telephone:

Question 1. Has competition resulted in better telephone service in your city? (a) As given by the independent telephone company?
Answers—Affirmative, 1,245; negative, 26.

(b) By an improved service on the part of the Bell Co.? Answers—Affirmative, 982; negative, 154.

Question 2. Has competition increased the number of telephone subscribers? Answers—Affirmative, 1,251; negative, 8.

Question 3. Has competition brought about greater civility and more courteous attention to the wants of the subscribers? Answers—Affirmative, 1,222 negative, 37.

Question 4. Have rates for telephone service been reduced by the advent of competition? (a) By the reduction of Bell rates formerly charged? Answers—Affirmative, 979; negative, 120.

(b) By the establishment of rates by the independent company lower than formerly prevailed? Answers—Affirmative, 1,236; negative, 45.

Question 5. In your judgment, would it be preferable to return to the conditions prevailing before the advent of the independent company? Answers—No, 1245; yes, 14.

Of this last fourteen, all but five qualified their answers, favoring a return to a single system only upon condition that they would be given the same service as they were now receiving and at the same price. Many of the other answers were very emphatic in opposing a return to conditions existing before competition.

The Manitoba Government, recognizing the futility of attempting to secure better telephone conditions from the Bell, is determined to establish a governmental system, and will endeavor to obtain the power to expropriate the Bell plant; should this be denied, however, it will nevertheless, if the people approve of the policy, build its own lines and exchanges, believing that competition will accomplish the desired results, as it has in the United States.

The Union of Manitoba Municipalities at a meeting last week, after spending two days in listening to testimony from telephone experts and officers, and then devoting a half day to discussion, at the close of its session, by a vote of eighty-six (86) to nineteen (19), passed a resolution recommending the municipalities in the Province to put in their own telephone systems in competition with the Bell. As already stated, telephone competition in Canada is practically in its infancy. The

Bell Telephone Company had made exclusive contracts with many of the railways and other corporations, some of which are now expiring. This, prior to the last two years, had made it almost impossible for the Independent companies to obtain a foothold. At the close of 1904 the Bell had approximately one telephone for every ninety (90) inhabitants. Their last report shows 78,195, or one to every seventy (70) inhabitants. The Independent companies in the meanwhile have installed 12,500 telephones, and everything indicates that they will make a gain of 200% in the coming year. In the State of Indiana, which has a population of approximately one-half of the Dominion of Canada, there is one Independent telephone for every fourteen persons, and in that State the Independents outnumber the Bell about three to one.

The Independent telephone interests to-day have a good organization, known as the International Independent Telephone Association of America. The organization formed in Detroit in 1897 for the purpose of defending damage cases brought by the Bell, finished its work by winning the last of the patent cases in 1904. In 1905 the Association was re-organized in Chicago under what is known as the "Ohio Plan." This plan starts with an organization in each State, which usually divides it into districts to suit local conditions, each of the districts having a complete organization of its own, subject to the control of the State body. The various companies are represented on the basis of the units they operate, a unit being one telephone or circuit mile of toll line. The district organizations select delegates to the annual meeting of the State Association on the basis of one representative for every one thousand units operated by their members. One delegate to the International Convention is allowed for each 10,000 units in the State. Each district selects a delegate to this Convention, the remainder necessary to make up the full quota being elected at the State meeting as delegates-at-large. At the district meetings all questions with reference to traffic conditions between the companies, the development of territory, etc., are considered. At the State meetings matters of general importance to the movement in the State are taken up.

The International Association holds its annual Convention between May 1st and July 1st. Permanent headquarters are

maintained in Cleveland, where a corps of secretaries and a map maker are employed for the purpose of keeping in touch with the development in the various States. At present there are over 7,000 Independent companies operating in over 12,000 cities and villages.

Our plan of organization is not a new one; it is based upon the Federal plan of Government, which has been in use in the counties, Congressional districts and States of the Union for more than a century. I believe it was Benjamin Franklin who first proposed a plan of this kind in 1754. It was known as the Albany plan, and outlined the formation of a separate government in each of the colonies, to be brought together in a central government for all of the united colonies. The plan under which our Association is operating seems broad enough to cover every possible contingency in keeping the Independent interests working together in harmony and as a complete system. It is often difficult for those not interested in the Independent telephone business to understand the enthusiasm of the people engaged in it. It is more than a mere means of livelihood to them; it is a *cause*, something worth fighting for. Perhaps this is true of any particular line of effort, but in no others I think to such an extent as in the Independent telephone business. This feeling is probably due in a measure to the interest attaching to the development of the industry, but more, I believe, to the conviction of practically all engaged in it that they are doing their part in a movement to benefit mankind. This feeling was never better expressed than by Judge Robert S. Taylor, who was appointed by President Cleveland to represent the United States Government in the famous Berliner patent case. Judge Taylor, in addressing a meeting at Chicago last summer, said: "I have never done anything in my life which I did with so much heart and so much earnestness as the fights I have made for Independent Telephony. I have never done anything I have felt so well satisfied with. I have always considered that no movement in this country that has ever taken place carried with it so much of a blessing to the people as the Independent telephone movement."

Aside from its many commercial and social advantages, the telephone has performed a very important part in advancing civilization, and there is little doubt that there would be much

more crime in the United States to-day were it not for the extensive use of the telephone. This, I think, is particularly true of the rural districts. The use of the telephone has lessened profanity; it is seldom that a profane word is heard over the wire; it has broadened all who use it to any extent in the choice of their language; something seems to prompt people using the telephone to talk their best. Of course, there are exceptions, but very little investigation on the part of any one will demonstrate the general truth of the statements just made.

There are to-day and will continue to be two great telephone systems; one, as at present, controlled and operated as a trust; the other, the Independent, operated as a complete system, reaching practically every farmer, all of the towns, and every important business center in the United States and Canada. The control of the securities and the management of the various companies making up this system to remain with local people. Consolidations will undoubtedly be made here and there to bring these companies into convenient groups, which in many cases will be county groups or Congressional District groups, tributary to large centers, reaching out a distance of fifty to one hundred miles. In my judgment, and I am by no means alone in this view, it would be unwise to consolidate them as one system, if, indeed, such a thing was possible. The telephone business is very largely a business of detail and requires the most careful management. This management must be in close touch with the other business interests of a community. No community can afford to depend upon a monopoly to supply its telephone service for the following reasons and many more that might be enumerated:

Competition: First—Guarantees fair rates.
Second—Secures at least fair management and courteous treatment from both systems.
Third—Stimulates the best thought of inventive minds in improving the apparatus, and the careful study of operating conditions with a view to greater efficiency.

Another advantage of competition—and I wish to call special attention to this because it is so often overlooked by the champions of a single system—is the almost absolute assurance it offers to the subscribers of both systems against being

deprived, by accident, of their telephone service. Even if the 70,000 telephones in your city were controlled by one company, many of your business men would still be compelled to have at least two telephones to take care of their business. In case of exchange trouble, fire, strikes, cable or line trouble in any particular section, you might be completely deprived of the use of your telephones until such trouble had been cleared. With instruments connected to both exchanges, the chances for this are almost entirely obviated. It is very seldom that both of your instruments will be out of order at once. The advantage of this until demonstrated by actual experience, as it has been in many cases, is not generally appreciated.

The increase in the use of the telephone has so far exceeded the anticipation of the most optimistic that it is hard to predict what it will be in the future. It is estimated that the United States will have a population of 200,000,000 in 1950; that population will require at least 50,000,000 telephones, more than seven times the present number. The telephone while increasing in usefulness will also be made a still greater means of pleasure and entertainment, and will be utilized for the transmission of concerts, sermons, political addresses, etc.; in fact, the Keystone Telephone Company of your city is now experimenting with such service.

Already the "seeing telephone," as exemplified in the "Televue," has been invented by J. B. Fowler, of San Diego, California. Long before 1950 this or a similar device will have been perfected, and by means of it, one may not only converse over the telephone, but actually *see* the person with whom he is speaking. Through the use of such a device, the police department will be able to transmit not only the description, but the photograph of a criminal wanted and to identify one instantly no matter where captured. Think of the convenience of shopping by telephone when one can not only order but view the goods purchased. When the telephone has been brought to its highest stage of usefulness, as our friend, Mr. Dooley, remarks, "th' legs will be as good f'r nawthin' as the appendix."

This talk would be incomplete without some reference to Independent telephone securities, for the progress of any industry, no matter how useful, depends upon its ability to show

proper returns upon the capital invested and to secure the capital necessary to its development. There is no reason to believe the Independent movement will be hampered through this cause. Already its securities are being favorably regarded by investors everywhere and they will, beyond question, in the very near future take their place on a par with the securities of other public serving corporations. There is no other utility which is in greater demand than the telephone, and statistics prove that panics have less effect on the gross income of wire using companies than on any others. It has been demonstrated that subscribers will economize, not only in luxuries but in their very necessities, in every way possible before giving up the telephone, and the telephone will continue to increase in usefulness and become a greater benefit and a more absolute necessity than at present. Thus the securities of the Independent telephone companies offer a safe and remunerative form of investment, and this fact thoroughly appreciated, there will be no lack of funds to develop the industry.

Telephony is desirable as a career for the young man. The electrical field is a broad one and experts do not believe that we have more than commenced to develop it. The telephone branch of the business offers peculiar advantages and attractions. With the marvelous growth there will come a demand for thousands of well trained young men in this field of labor. Already telephone courses have been established at universities and colleges, and the demand for some of the technically trained students is so great that employment is offered them before they have finished their course. As telephony progresses the men with technical training will be more and more in demand. I, therefore, commend this branch of the electrical field to the students of all technical schools as one worthy of their consideration. They will find that it not only offers them employment but will give them splendid opportunities for careful study and the development of economies and new improvements that will result in financial benefit to themselves and be of untold advantage to mankind.

Section of Physics and Chemistry.

(Stated meeting held Thursday, January 10th, 1907.)

The Analysis of Chalybeate Waters.*

By C. Chester Ahlum.

Chalybeate waters may be those containing ferrous carbonate held in solution by carbonic acid, or those containing iron sulphates, the latter substances being the product of oxidation of iron pyrites encountered by the water. Sulphuric acid is another product of the oxidation and will also be found in the water.

If the water containing these substances comes in contact with limestone, calcspar or dolomite another reaction takes place, namely, the sulphuric acid will decompose these minerals with the formation of calcium and magnesium sulphates and carbon dioxide, hence becoming heavily charged with these substances in addition to the iron sulphates.

The presence of the iron sulphates is very detrimental to steam-boilers, and in the bituminous coal regions of Western Pennsylvania great difficulty is experienced by some mine operators in obtaining a supply of water fit for steam producing. In a certain locality many wells have been driven, but in nearly every instance they were found to be absolutely worthless, being heavily charged with sulphuric acid, calcium, magnesium and iron sulphates, the latter very often to the extent of 500 grains per gallon.

To treat a water of this character for boiler purposes is utterly impossible, and some operators are obliged to haul water five or six miles from a better source.

*Read by title.

Because of the readiness with which iron undergoes oxidation from the mere presence of air, we will find it in both conditions, ferrous and ferric, and therefore the regular method of analysis will require modification.

The method employed by the writer is as follows:—

Iron oxide and alumina.—200 c.c. of the filtered water are boiled down to 50 c.c. after acidifying with hydrochloric acid and adding 2 c.c. of concentrated nitric acid. Ammonium hydroxide is added until the iron and alumina is completely precipitated. It is then filtered off, washed, dried, ignited and weighed as $Fe_2O_3 + Al_2O_3$.

The residue in the crucible is dissolved in a very small quantity of hydrochloric acid. The solution is then transferred to a 250 c.c. erlenmeyer flask containing 50 c.c. of water and 5 c.c. of concentrated sulphuric acid. The iron in solution is reduced to the ferrous state in the ordinary way using metallic zinc and after being reduced is then titrated with N/10 potassium permanganate.

The amount of iron obtained from the titration is deducted from the total weight of the iron oxide and alumina, giving the weight of the alumina present in the combined precipitate.

Calcium oxide.—To the filtrate from the iron oxide and alumina is added in slight excess a strong solution of ammonium oxalate. After standing for twelve hours the precipitate is filtered off, washed with water and dissolved in moderately strong sulphuric acid, which is then titrated with N/10 potassium permanganate.

Magnesium oxide.—To the filtrate from the calcium oxalate is added a small quantity of ammonium hydroxide and then a solution of disodium hydrogen phosphate. After standing twelve hours the precipitate is filtered off and washed with a mixture of 1000 c.c. of water, 500 c.c. of ammonium hydroxide and 150 grams of ammonium nitrate. The precipitate is then ignited and weighed as $Mg_2P_2O_7$.

Sulphur trioxide.—200 c.c. of the filtered water are acidified with hydrochloric acid and heated to boiling. Barium chloride is then added in slight excess and allowed to stand until the precipitate has settled. It is then filtered off, washed, dried, ignited and weighed as $BaSO_4$.

Chlorine.—100 c.c. of the filtered water are acidified with

nitric acid and silver nitrate added in slight excess. The liquid is brought to a boil, filtered, washed, dried, ignited and weighed as AgCl.

Silica, sodium and potassium oxides.—500 c.c. of the filtered water are evaporated to dryness in a platinum dish on a water bath, treated with dilute hydrochloric acid and again evaporated to dryness. The residue is then extracted with a little dilute hydrochloric acid, the insoluble silica filtered off, dried, ignited and weighed as SiO_2.

To the filtrate is added in slight excess, a solution of barium hydroxide. The liquid is then boiled, filtered and washed, and to the filtrate is added a few drops of ammonium hydroxide, then a solution of ammonium carbonate as long as a precipitate forms. The solution is allowed to stand for some time, stirring occasionally until the precipitate becomes granular. It is then filtered and the precipitate washed with water containing a few drops of ammonium hydroxide and a very small quantity of ammonium carbonate. The filtrate after being acidified with a few drops of hydrochloric acid, is evaporated to dryness in a platinum dish over a water bath. The dish containing the residue is then heated to about 140° in an air bath, and then heated to dull redness over a burner to expel ammonium salts.

The residue is then dissolved in 10 c.c. of water, a few drops of barium hydroxide are added, then a few drops of ammonium hydroxide, and finally is added in excess a solution of ammonium carbonate. After allowing to stand for some time it is filtered and the precipitate washed with water containing a few drops of ammonium hydroxide and a small quantity of ammonium carbonate.

The filtrate is then evaporated to dryness after acidifying with hydrochloric acid. The dish with the residue is heated to 140° in an air bath and then a dull redness over a burner to expel ammonium salts. It is then cooled in a desiccator and weighed as $NaCl + KCl$.

The residue is redissolved in 10 c.c. of water and to the solution is added a drop of hydrochloric acid and then platinic chloride in excess. It is then evaporated nearly to dryness, 20 c.c. of alcohol are added, and after all the red sodium salt is dissolved, is filtered on a tared filter, washed with alcohol, dried and weighed as K_2PtCl_6.

This weight multiplied by .30701 gives the weight of potassium chloride which, when subtracted from the weight of the mixed chlorides, gives the weight of sodium chloride.

Iron in ferrous condition.—200 c.c. of the filtered water are acidified with about 10 c.c. of concentrated sulphuric acid and titrated with N/10 potassium permanganate.

Total solids.—100 c.c. of the filtered water are placed in a weighed platinum dish and evaporated to dryness on a water bath. The dish with the residue is dried at 100°, cooled and weighed. The residue is dissolved out quickly with dilute sulphuric acid and titrated with N/10 potassium permanganate.

In reporting the analyses with the bases and acids expressed in their probable combination, the following rule is followed:—The chlorine is combined with the sodium and if in excess with the potassium, then with magnesium and finally calcium, iron and aluminum, in the order named. The sulphur trioxide is combined with the sodium first, if there was not enough chlorine to satisfy this base, then with potassium and finally calcium, magnesium, aluminum and iron, in the order named. The calcium and magnesium in excess are calculated to carbonates and any iron alumina in excess as iron oxide or alumina.

To show the method in detail, the following analysis is given:—

Weight of total solids	.8123	grams	(100 c.c. of water)
" " $Fe_2O_3+Al_2O_3$	.5214	"	(200 c.c. of water)
" " $BaSO_4$	2.4806	"	(200 c.c. of water)
" " AgCl	.0137	"	(100 c.c. of water)
" " $Mg_2P_2O_7$	.1312	"	(200 c.c. of water)
" " SiO_2	.0131	"	(500 c.c. of water)
" " NaCl+KCl	.3552	"	(500 c.c. of water)
" " K_2PtCl_4	.0182	"	(500 c.c. of water)

Titration.—Iron in ferrous state, 60.1 c.c. of N/10 potassium permanganate (200 c.c. of water).

Titration.—Iron in ferrous state after evaporation, 23.2 c.c. of N/10 potassium permanganate (100 c.c. of water).

Titration—Calcium oxalate, 18.1 c.c. of N/10 potassium permanganate.

Titration.—Iron from the mixed precipitate $Fe_2O_3+Al_2O_3$—62.5 c.c. of N/10 potassium permanganate.

Factors.

1 c.c. of potassium permanganate	$=.0072$ grams	FeO	
1 c.c. " " "	$=.0080$ "	Fe_2O_3	
1 c.c. " " "	$=.0038$ "	CaO	
1 c.c. " " "	$=.0008$ "	Oxygen	
$BaSO_4 : SO_3 = .34291$		$2NaCl : Na_2O = .53076$	
$AgCl : Cl = .24726$		$2KCl : K_2O = .63183$	
$Mg_2P_2O_7 : MgO = .36190$		$K_2PtCl_6 : 2KCl = .30701$	

The weights of the bases and acids found are corrected to 100 c.c. of water.

Weight of $NaCl + KCl$ .... .3552
Weight of $KCl = .0182 \times .30701 =$ .... .0056

Weight of NaCl .... .3496
Weight of Na_2O in 100 c.c. of water............$(.3496 \times .53076) \div 5 = .0371$
Weight of K_2O in 100 c.c. of water............$(.0056 \times .63183) \div 5 = .0007$

Weight of $Fe_2O_3 \div Al_2O_3$ .... .5214
Weight of Fe_2O_3 from titration .... .5000

Weight of Al_2O_3 .... .0214
Weight of Fe_2O_3 in the mixed precipitate..............$62.5 \times .008 = .5000$
Fe_2O_3 in 100 c.c. of water............ $.5000 \div 2 = .2500$
Al_2O_3 in 100 c.c. of water............ $.0214 \div 2 = .0107$

Weight of MgO in 100 c.c. of water ....$(.1312 \times .3619) \div 2 = .0237$
Weight of Cl in 100 c.c. of water .... $.0137 \times .24726 = .0033$
Weight of SiO_2 in 100 c.c. of water .... $.0131 \div 5 = .0026$
Weight of CaO in 100 c.c. of water ....$(18.1 \times .0028) \div 2 = .0253$
Weight of SO_3 in 100 c.c. of water ....$(2.4806 \times .34291) \div 2 = .4253$
Weight of FeO in 100 c.c. of water ....$(60.1 \times .0072) \div 2 = .21636$
.21636 grams of FeO $= .2404$ grams of Fe_2O_3
Weight of Fe_2O_3 in 100 c.c. of water .... $.2500 - .2404 = .0096$

Correction of the total solids.—When the water is evaporated to dryness on the water-bath, oxygen will be absorbed by the ferrous salts during the exposure to the air. The amount of oxygen absorbed is determined by the difference in the amount of N/10 potassium permanganate required by the ferrous salts before evaporation and the amount required after.

$(60.1 \div 2) = 30.0$ c.c. N/10 $KMnO_4$ required by the ferrous salts in 100 c.c. before evaporation.
23.2 c.c. N/10 $KMnO_4$ required by the ferrous salts in 100 c.c. after evaporation.
6.8 c.c. N/10 $KMnO_4$ difference

The amount of oxygen absorbed from the air is equivalent to

the amount of available oxygen of the N/10 potassium permanganate.

Weight of solids	.8233
Weight of oxygen absorbed (6.8 × .0008)	.0054
Weight of corrected solids	.8179
Weight of free H_2SO_4 (see next page)	.0256
Weight of corrected solids (final)	.7923

The free sulphuric acid will go into combination during the oxidation and will therefore increase the weight of solids.

Collecting the results we obtain the following:—

	grams per. 100 c.c.	grams per. 1000 c.c.
Sodium oxide	.0371	.3710
Potassium oxide	.0007	.0070
Calcium oxide	.0253	.2530
Magnesium oxide	.0237	.2370
Ferrous oxide	.2164	2.1640
Ferric oxide	.0096	.0960
Alumina	.0107	.1070
Sulphur trioxide	.4253	4.2530
Chlorine	.0033	.0330
Silica	.0026	.0260

Carrying out the rule of combining the acids and bases we obtain the following:—

	grams per. 1000 c.c.
Sodium chloride	.0540
Sodium sulphate	.7190
Potassium sulphate	.0130
Calcium sulphate	.6150
Magnesium sulphate	.7110
Aluminum sulphate	.3580
Ferrous sulphate	4.5680
Ferric sulphate	.2400
Silica	.0260
Organic, etc.	.6190
Total solids	7.9230
*Sulphuric acid (free)	.2560

*Because of the presence of sodium chloride, part of the free acid may be expressed as hydrochloric if preferred. The amounts of sulphuric acid, sodium sulphate and chloride will therefore require correction. For direct estimation of free acid see 470-473 J. Chem. Soc. (London), Vol. 89.

With waters containing ferrous carbonate, the regular methods of analysis are followed and any iron that has become oxidized is stated as ferric oxide. The ferrous iron is estimated by standard potassium permanganate.

Laboratory of Geo. W. Lord Company, Philadelphia.

DESTRUCTIVE FLOODS IN 1905.

The destructive floods that occurred in the United States during 1905 are described by Mr. Edward Charles Murphy and other hydrographers of the United States Geological Survey in a recent publication of that bureau, which is listed as Water-Supply and Irrigation Paper No. 162. The very destructive floods of that year were few. The most remarkable flood or series of floods of the year were those in Gila River Basin, in Arizona. From January 15 to April 30 occurred a series of seven floods—almost a continuous flood—remarkable for the total volume of flow. In November there was in this basin another flood, which was notable for its magnitude, being the largest on record on Salt River. The other large floods of the year occurred on comparatively small streams. Few lives were lost and the damage was small compared with that of some previous years.

Among the floods described in this paper are those on Poquonnock River, Connecticut, on Sixmile Creek and Cayuga Inlet, New York, on the Unadilla and Chenango Rivers, New York, on Allegheny River, Pennsylvania-New York, on Devil's Creek, Iowa, on Purgatory River, Colorado, on Pecos River, New Mexico-Texas, on Hondo River, New Mexico, on Rio Grande, New Mexico-Texas, in Colorado River Basin and in Gila basin.

A discussion of the flood discharge and the frequency of floods in the United States together with an index to the literature of American floods adds to the value of this paper. Maps and views to the number of fifteen are included. Besides Mr. Murphy, the chief contributors to the paper are Messrs. T. W. Norcross, R. E. Hotron, C. C. Covert, and F. W. Hanna. It is published for free distribution, and application for it should be made to The Director of the United States Geological Survey, Washington, D. C.

PRODUCTION OF SILVER IN 1905.

The production of silver increased in quantity from 55,999,864 ounces in 1904 to 56,101,594 ounces in 1905, a gain of 101,730 ounces; but it increased in commercial value from $32,035,378 in 1904 to $34,221,972 in 1905, a gain of $2,186,594.

PRODUCTION OF GOLD IN 1905.

The production of gold in the United States increased from 3,910,729 ounces, valued at $80,835,648, in 1904, to 4,265,742 ounces, valued at $88,180,-711, in 1905, an increase of 355,013 ounces in quantity, and of $7,345,063 in value.

REPORTS OF STREAM MEASUREMENTS.

The last of the fourteen papers covering the progress of stream measurements for the calendar year 1905 has recently been issued by the United States Geological Survey, so that the series is now complete. They are listed under the head of Water Supply and Irrigation Papers and range in number from 165 to 178 inclusive. The region covered in each paper is indicated by subtitles, which are as follows:

165. Atlantic coast of New England drainage.
166. Hudson, Passaic, Raritan and Delaware River drainages.
167. Susquehanna, Gunpowder, Patapsco, Potomac, James, Roanoke, and Yadkin River drainages.
168. Santee, Savannah, Ogeechee, and Altamaha Rivers and eastern Gulf of Mexico drainages.
169. Ohio and lower eastern Mississippi River drainages.
170. Great Lakes and St. Lawrence River drainages.
171. Hudson Bay and upper eastern and western Mississippi River drainages.
172. Missouri River drainage.
173. Meramec, Arkansas, Red and lower Western Mississippi drainages.
174. Western Gulf of Mexico and Rio Grande drainage.
175. Colorado River drainage above Yuma.
176. Great Basin drainage.
177. Great Basin and Pacific Ocean drainages in California, and Colorado River drainage below Gila River.
178. Columbia River and Puget Sound drainages.

A limited number of these papers are held by the Geological Survey for free distribution. and a number have been delivered to Senators and Representatives in Congress for free distribution. Applications sent to the Survey should be addressed to The Director, United States Geological Survey, Washington, D. C.

MODERN BATTLESHIP CONSTRUCTION.

Owing to the developments of the Japanese sea force and the lead of England in the matter of battleship construction of great size, other nations are joining in the race for supremacy in the single battle unit. The English type ship Dreadnaught is of 18.500 tons displacement. Japan is building two, in native dockyards, of 19,500 tons each. Germany has two of 19.000 tons under contract. France has taken steps looking to the acquisition of six of 18,000 tons each. The United States has one under authorization to displace probably 20,000 tons. At present writing there seems to be little disposition to limit the size of new constructions; the whole tendency is a reaching out into new fields of size and character, a general disposition to relegate medium-sized guns to the scrap heap being the most prominent individual characteristic of the new ships. Speeds are being raised above those of previous types, which multiplies largely the construction of each unit.—*Iron Age.*

(Stated meeting held Thursday, October 11th, 1906.)

Tax-Free Alcohol.*

By Albert P. Sy,

University of Buffalo.

On account of its relation to many important industries in the United States, especially its relation to chemical manufacturing, its use for light and heat, its use in gas engines, the subject of tax-free alcohol becomes of great importance, and for this reason has been much discussed and much has been written about it lately. It is believed that a short review of the alcohol industry might be of interest to the readers of this *Journal*.

After about eighteen years of attempted legislation in this direction there has been passed by the House of Representatives and the Senate and signed by the President a bill which becomes operative in 1907 and which removes the internal revenue tax on grain alcohol.

On account of its importance, the text of the new law is herewith given in full, as follows:

THE "FREE ALCOHOL" LAW.

Below is presented the text of the new law providing for tax-free denatured alcohol for use in the arts and industries, but not in the manufacture of beverages or liquid medicines:

AN ACT

For the withdrawal from bond, tax free, of domestic alcohol when rendered unfit for beverage or liquid medicinal uses by mixture with suitable denaturing materials.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That from and

*Read by title.

after January 1st, 1907, domestic alcohol of such degree of proof as may be prescribed by the Commissioner of Internal Revenue, and approved by the Secretary of the Treasury, may be withdrawn from bond without the payment of internal revenue tax, for use in the arts and industries, and for fuel, light, and power, provided said alcohol shall have been mixed in the presence, and under the direction, of an authorized government officer, after withdrawal from the distillery warehouse, with methyl alcohol or other denaturing material or materials, or admixture of the same, suitable to the use for which the alcohol is withdrawn, but which destroys its character as a beverage, and renders it unfit for liquid medicinal purposes; such denaturing to be done upon the application of any registered distillery, in denaturing bonded warehouses specially designated or set apart for denaturing purposes only, and under conditions prescribed by the Commissioner of Internal Revenue, with the approval of the Secretary of the Treasury. The character and quantity of the said denaturing material and the conditions upon which said alcohol may be withdrawn free of tax shall be prescribed by the Commissioner of Internal Revenue, who shall, with the approval of the Secretary of the Treasury, make all necessary regulations for carrying into effect the provisions of this Act.

Distillers, manufacturers, dealers and all other persons furnishing, handling or using alcohol withdrawn from bond under the provisions of this Act shall keep such books and records, execute such bonds and render such returns as the Commissioner of Internal Revenue, with the approval of the Secretary of the Treasury, may by regulation require. Such books and records shall be open at all times to the inspection of any internal revenue officer or agent.

Section 2. That any person who withdraws alcohol free of tax under the provisions of this Act and regulations made in pursuance thereof, and who removes or conceals the same, or is concerned in the removing, depositing or concealing the same for the purpose of preventing the same from being denatured under governmental supervision, and any person who uses alcohol withdrawn from bond under the provisions of Section one of this Act for manufacturing any beverage or liquid medicinal preparation, or knowingly sells any beverage or liquid medicinal preparation made in whole or in part from such alcohol, or knowingly violates any of the provisions of this Act, or who shall recover or attempt to recover by redistillation or by any other process or means, any alcohol rendered unfit for beverage or liquid medicinal purposes under the provisions of this Act, or who knowingly uses, sells, conceals, or otherwise disposes of alcohol so recovered or redistilled, shall on conviction of each offense be fined not more than $5.000, or be imprisoned not more than five years, or both, and shall in addition, forfeit to the United States all personal property used in connection with his business, together with the buildings and lots or parcels of ground constituting

the premises on which said unlawful acts are performed or permitted to be performed: Provided, That manufacturers employing processes in which alcohol used free of tax under the provisions of this Act, is expressed or evaporated from the articles manufactured, shall be permitted to recover such alcohol and to have such alcohol restored to a condition suitable solely for reuse in manufacturing processes under such regulations as the Commissioner of Internal Revenue, with the approval of the Secretary of the Treasury, shall prescribe.

Section 3. That, for the employment of such additional force of chemists, internal revenue agents, inspectors, deputy collectors, clerks, laborers, and other assistants as the Commissioner of Internal Revenue, with the approval of the Secretary of the Treasury, may deem proper and necessary to the prompt and efficient operation and enforcement of this law, and for the purchase of locks, seals, weighing beams, gauging instruments, and for all necessary expense incident to the proper execution of this law, the sum of $250,000, or so much thereof as may be required, is hereby appropriated out of any money in the treasury not otherwise appropriated, said appropriation to be immediately available.

For a period of two years from and after the passage of this Act the force authorized by this Section of this Act shall be appointed by the Commissioner of Internal Revenue, with the approval of the Secretary of the Treasury, and without compliance with the conditions prescribed by the Act entitled "An Act to regulate and improve the civil service," approved January 16th, 1883, and amendments thereof, and with such compensation as the Commissioner of Internal Revenue may fix, with the approval of the Secretary of the Treasury.

Section 4. That the Secretary of the Treasury shall make full report to Congress at its next session of all appointments made under the provisions of this Act, and the compensation paid thereunder, and of all regulations prescribed under the provisions hereof, and shall further report what, if any, additional legislation is necessary, in his opinion, to fully safeguard the revenue and to secure a proper enforcement of this Act.

A bill in one form or another, for the purpose of obtaining tax-free alcohol had been introduced many times previously, but other interests were so strong that these bills never came out of the committees to whom they were referred. The chief opponents were those interested in mineral oils (gasolene, kerosene, etc.,) and the manufacturers of wood alcohol. The mineral oil industry, which is controlled by the Standard Oil Co., which is one of the most powerful and gigantic trusts or monopolies in the world, saw in tax-free alcohol a serious competitor. The same is true of the wood alcohol manufacturer,

whose product, being tax-free, can be sold at a considerably lower price than grain alcohol and still bring an enormous profit. Of course those interested in wood alcohol could readily see that with no tax on grain alcohol, wood alcohol could not compete with it, since it costs more to produce the wood alcohol. While the bill which has just been passed was under consideration, the wood alcohol manufacturers brought great pressure to bear against it; they appeared repeatedly before the committee, urging that the entire wood alcohol industry, which is quite extensive, would be ruined, and many workmen would be thrown out of employment. Their principal argument against tax-free alcohol was that there would be an increase in the use of alcoholic beverages and consequently an increase of drunkenness and misery. However one can easily see the weak points in all these arguments. It does not follow that tax-free grain alcohol would ruin the wood alcohol industry, since there are a great many purposes for which wood alcohol would still be used in preference to denatured grain alcohol. There will be considerable demand for the former for denaturing purposes, in fact it is estimated that the present output of wood alcohol will not be sufficient to supply the demand for denaturing purposes. Wood alcohol is necessary for making formaldehyde. While perhaps a comparatively few workmen would be thrown out of employment at first as a result of the decrease in demand for wood alcohol, yet thousands of others would find employment in the grain alcohol industry, not only those directly connected with the distilleries, but those who produce the raw materials. would require extra help.

The denaturing materials are not mentioned in the bill, but the commissioner will no doubt follow the customs of other countries and use crude wood alcohol and some product containing pyridine bases. This would leave the alcohol best suited for most purposes and at the same time effectively produce a disgusting flavor and make it poisonous. Prominent chemists testified before the committee that illicit recovery is impossible without distillation, and even then it is difficult. The wood alcohol manufacturers attempted to show that illicit recovery is easy, but investigation convinced them that such is not the case. The writer of this made several series of experiments which showed that even a partial and unsatisfactory

recovery is exceedingly difficult, and in most cases impossible.

All other nations of commercial importance allow the use of alcohol in the arts and for industrial purposes tax free. One of the reasons why previous legislation for tax-free alcohol has failed in the United States is that it was thought that on account of the high tax on alcohol for beverages there would be great temptation for fraud upon the revenue. In the past the question has also been misunderstood with reference to the use of alcohol for medicines; if alcohol were to be used tax-free for medicinal compounds there would be great difficulty in guarding the revenue. For this reason the original bill was changed so as to eliminate the clauses relating to the use of tax-free alcohol for medicines. While it is believed by some that there will be fraud upon the revenue, yet other countries have had no difficulty in this respect. The Secretary of the Treasury and the Commissioner of Internal Revenue both agree that the new bill can be enforced and fraud avoided. There are at present two exemptions for tax on alcohol, namely, for fortifying wines and for making vinegar, and the Commissioner reports that there is practically no fraud upon the revenue under these exemptions.

It will not be necessary to give details of manufacture of either wood or grain alcohol, except to mention the fact that in the United States grain alcohol is made mostly from starchy grains instead of from potatoes as in Germany and some other countries. The grain usually used is maize or Indian corn. Of this there is grown an enormous amount in the United States annually, and with an increased demand for alcohol, the production of corn as well as other grains and vegetables will be greatly increased, and agricultural conditions will be greatly benefitted by the new bill.

With reference to the cost of production of grain alcohol, the following points were brought out before the committee, the data being obtained from the books of a large distillery in Peoria, Illinois: The average price paid for corn for ten years was 42.36 cents per bushel; the average amount of alcohol from a bushel of corn was 4.76 proof gallons (50%); the average cost of a proof gallon was 10.78 cents. The cost of corn for one proof gallon was 8.89 cents; subtracting this 8.89 from the total cost, 10.78, there is left 1.89 cents as the cost of

making one proof gallon of alcohol. At this rate it would cost 3.4 cents per gallon to make 90% alcohol, or a total cost of 19.4 cents per gallon, including the corn. Lately the methods for producing alcohol have been improved so that about 5 proof gallons can be made from one bushel of corn, or the total cost of a gallon of 90% alcohol is 18.4 cents.

With reference to the amount of alcohol that may be produced from corn and potatoes, Secretary Wilson, of the Department of Agriculture, said that one acre will produce (average) 50 bushels of corn from which there can be made 882 pounds of absolute alcohol, or about 130 gallons, which corresponds to about 140 gallons of 95% alcohol. One acre will produce 18,000 pounds of potatoes, from which 1620 pounds of absolute alcohol or 255 gallons of 95% alcohol can be made.

Before the same committee a representative of farmers organizations said that with corn at 30 cents a bushel, yielding 2.5 gallons of 95% alcohol, the total cost of making one gallon would be about 12 cents a gallon, and could be sold for 20 cents a gallon.

An enormous amount of starchy material goes to waste annually in the stalks of the corn, i. e., in the plant itself, which in most cases is not removed from the land. With commercially practical methods for recovering and utilizing this waste, the production of alcohol per acre of corn can be greatly increased. The Department of Agriculture has been making experiments, using corn cobs and stalks for making alcohol; it is believed that this will develop into an industry of considerable commercial importance. These materials have heretofore been allowed to go to waste. Experiments made at Hoopeston, Ill., in the corn district of that State, have shown that sufficient alcohol can be recovered from these raw materials to justify the erection of a distilling plant. According to reports, eleven gallons of alcohol have been obtained from a ton of green cobs, while a ton of green stalks yielded six gallons.

Another important source of alcohol is the low grades of molasses, those grades that can not be sold as molasses. In Central and Southern America and the West Indies there are produced annually millions of gallons of low grade molasses, which at present are burned, destroyed or fed to animals; a small proportion is brought to this country to be worked up

into liquors. While this material is much cheaper than corn as a source of alcohol, it produces an alcohol which is unfit for making beverages on account of the odor and taste which it derives from the molasses. But for industrial purposes where this alcohol can be used tax-free this odor and taste are no objections. On account of its cheapness, this molasses is considered by some as the most important source of alcohol at present not developed.

In Cuba alcohol is now made from this molasses at a cost of 10 cents per gallon according to a report of United States Minister Squires. In the United States this molasses can be bought for 3 cents per gallon, and it takes about 2 gallons to make a gallon of alcohol; with a cost of 3.4 cents per gallon for making, 90% alcohol from this source would cost 9.4 cents to produce.

Another source of alcohol is the low grade molasses produced in the manufacture of sugar from beets. Ten factories in the State of Michigan produced enough of this molasses which was converted into one million proof gallons of alcohol in a distillery in that State. While at present the beet sugar industry is still in its infancy, it is obvious that with its development this will furnish a byproduct of importance in the alcohol industry.

The pulp of the coffee berry, which was formerly a waste product, is now used in Mexico and South America for making alcohol.

The total cost of production of a gallon of wood alcohol is greater than that of a gallon of grain alcohol, but with no internal revenue tax on the former, it could be sold considerably cheaper than the latter and still leave a big profit. At present the prices of the various grades of wood alcohol, according to quotations from the Wood Products Co., of Buffalo, N. Y., are as follows:

95% alcohol,	80 cents per gallon,	or	70 cts. in barrel lots.
97% "	90 " "	" "	75 " " " "
Columbian Spirits (99%)	$1.35 " "	"	$1.25 " " "

Many chemical manufacturing interests will be greatly benefitted by tax-free alcohol, and much is hoped for in the development of our chemical industries in the near future. Denaturated alcohol would be used in the following industries

where wood alcohol is chiefly used now: Anilin colors, organic chemicals, transparent soaps, celluloid, smokeless powder, fulminates, photographic materials, and many other manufactories where alcohol is used for finishing and painting.

Methyl alcohol is used to some extent in the manufacture of smokeless powders and explosives, but it is believed by some that a better and more stable product can be made by using grain alcohol; experts in the Ordnance Department of the U. S. Army say that in making smokeless powder a better colloid is produced when grain alcohol is used; the Government requires that smokeless powders made for use in the army shall be made by using grain alcohol free from methyl alcohol. The Ordnance Department of the U. S. Army does not have its own powder manufactory, but the powders are made under contract by private firms; these firms are allowed one pound of alcohol tax-free for every pound of powder which they make for the Government. Tax-free alcohol will therefore affect the price of smokeless powders for consumers other than the Government.

Of greatest importance, however, will be the use of tax-free alcohol for illuminating and heating purposes; it will displace the gasolene and coal oil which are now the universal liquid fuels. These petroleum products are now controlled by a trust, the Standard Oil Company, and there has been a steady rise in the price of these commodities from year to year. President Roosevelt, in his last message, says: "The Standard Oil Co. has, largely by unfair or unlawful methods, crushed out competition. It is highly desirable that an element of competition be introduced by the passage of some such law as that which has already passed the House, putting alcohol for use in the arts and manufacturies on the free list." Since the President wrote this, the free alcohol bill passed both House and Senate and received his signature.

Free alcohol will surely prove a most effective element of competition, and it is hard to understand how any trust or monopoly can ever control it. It is not pumped from wells in certain parts of the country, but can easily be made from a great variety of materials of practically unlimited supply in many parts of the country.

Alcohol will displace petroleum products and coal gas for

illuminating purposes; in countries where alcohol is tax-free it is now successfully used for lighting purposes. The Auer alcohol lamp, it is claimed, produces a cheaper and better light than coal oil. Experiments with alcohol and kerosene as to candle power and cost have shown that alcohol at 31 cents per gallon is cheaper for illuminating purposes than kerosene at 15 cents per gallon; this becomes still more important when we consider that kerosene costs more than 15 cents per gallon and is going up in price from year to year, while it is expected that with the development of the alcohol industry, the alcohol will be produced for less than 31 cents per gallon. An expert of the Department of Agriculture, speaking of the use of alcohol in Germany, says, in "The Gas Engine:" For lighting purposes, as alcohol gives a non-luminous flame, a chemical mantle similar to a Welsbach burner, is used, which produces a very bright and economical light, costing but one cent per hour for 71 candle power. In a report of Mr. Payne, of the Ways and Means Committee of the House of Representatives, it is stated that experiments have been made comparing an alcohol Welsbach lamp with the most approved pattern of kerosene lamps with round wicks and of equal candle power it was found that a gallon of alcohol would burn twice as long as a gallon of kerosene; if, therefore, alcohol costs less than twice as much as kerosene, it is the cheaper material for illuminating purposes, not considering its other advantages, such as absence of odor, greater safety and cleanliness.

Another important use of alcohol will be as a fuel, displacing wood, coal, coal gas, natural gas, and the various petroleum products. The question of a cheap and efficient fuel is of considerably greater importance than is usually believed; the supply of wood, coal and gas is limited, the demand for them is increasing; a substance must be found as a substitute, and in the near future. Tax-free alcohol will be such a substitute, the raw materials for which can be produced from year to year according to the demand for it. The fuel question is especially important in the western part of the United States, where the supply of soft coal is becoming low and hard coal is too expensive on account of the great cost of transportation from the source of supply in the East.

Alcohol is a more efficient fuel than the petroleum products

and has many other desirable advantages; it is a much cleaner substance to use, does not have as disagreeable an odor, and is burned completely more readily than petroleum products; its products of combustion are less disagreeable, it is less dangerous to handle, it is more safely shipped and stored, and most important of all, it is less volatile and less dangerous when used than petroleum products.

In cities, natural and manufactured gases are used extensively for heating; besides the advantages already mentioned, alcohol has the advantage over gaseous fuel that it can not become poisonous and that there is no expense of laying pipes and gas fitting, no interruptions in supply on account of repairs or accidents, and no danger from leaks, which, in the case of gas, are responsible for hundreds of deaths each year.

A most important use of alcohol will be its use in power engines. Many experiments have been made and it has been shown that alcohol can be used instead of gasolene, and with many advantages. Although the heat of combustion of alcohol is less than that of gasolene, yet it is claimed that twice as large a percentage of heat can be utilized and converted into work than can be done from gasolene; there is less heat thrown off in the waste gases from the combustion of an alcohol vapor and air mixture than there is in those from gasolene vapor and air mixture.

Mr. Goebbels, who is connected with a company making gas engines, states that they have made experiments to adapt alcohol for use in gas engines, and that 20% more power can be obtained from alcohol than from gasolene. Other experiments have shown that alcohol vapor and air forms a more perfect and reliable explosive mixture than gasolene vapor and air; the latter mixture is subject to spontaneous combustion and apt to explode prematurely on compression, and there is greater liability of incomplete combustion. Experiments are now being made in every country to adapt and perfect gas engines for the use of alcohol as a substitute for gasolene. In the earlier forms of alcohol engines alcohol alone could not be used, but a mixture of alcohol and gasolene, generally about 25% of the latter in the mixture, was found to work to advantage, this mixture being more readily ignited.

Extensive experiments are being made in England with al-

cohol motors for agricultural purposes; alcohol engines are especially adapted for supplying stationary power on farms, for pumping water, cutting and grinding feed, threshing and many other operations. As a motive fuel for agricultural implements, alcohol will supply the need for the Western farmer who lives too far from the supply of coal or other fuel, and who needs a great amount of power for his large farms and crops.

Summarizing the advantages of alcohol over other fuels we have the following:

It is cheaper, more reliable and efficient.

It is much cleaner to handle and use.

There is no danger from poisoning like there is in the use of natural or manufactured gases.

It does not have any disagreeable odor and its products of combustion are not objectionable.

It is less volatile and less dangerous to use, handle and store. Everybody is acquainted with the dangers of gasolene; insurance companies increase cost of, or refuse, insurance when gasolene comes into consideration.

An alcohol fire can be easily put out with water. since the latter readily mixes with alcohol in all proportions; a gasolene or oil fire can not be quenched with water; the latter only scatters the burning material.

When gasolene or oil leaks or is spilled it becomes dangerous and disagreeable and can be removed only with difficulty. Alcohol can easily be removed with water.

WHAT IS MEANT BY THE WORD ARTESIAN

The significance of the term "artesian" is discussed with great care by Mr. Myron L. Fuller of the United States Geological Survey in Water-Supply and Irrigation Paper No. 160. While there is considerable diversity of practice there is nevertheless a general tendency to give the term one or the other of two meanings, and about fifty geologists throughout the country have expressed their willingness to accept any definition agreed on by the majority of active workers on underground-water problems.

Discussing the original use of the term artesian (as applied to flowing wells first observed in the town of Artois, France), the use of the word in recent scientific literature, in Europe, and the present scientific and popular use of the term in this country, Mr. Fuller makes clear that no definite meaning can be assigned to the word artesian in a publication unless a defi-

nition is given in the same paper. It is even found that the same writer employs it differently in different publications.

The predominant scientific usage of the term is for all wells in which the water rises; in other words, for those exhibiting the hydrostatic or artesian principle. In popular practice it is applied, in addition to the uses previously mentioned, to deep wells in general, especially those in rock, and to a certain extent to any drilled wells yielding water of good sanitary quality.

After discussing the arguments for these various uses, Mr. Fuller gives the following definitions which were agreed on by the members of the Division of Hydrology of the Survey as the most expedient at the present time.

Artesian principle.—The artesian principle, which may be considered as identical with what is often known as the hydrostatic principle, is defined as the principle in virtue of which water confined in the earth's crust tends to rise to the level of the water surface at the highest point from which pressure is transmitted. Gas as an agent in causing the water to rise is expressly excluded from the definition.

Artesian pressure.—Artesian pressure is defined as the pressure exhibited by water confined in the earth's crust at a level lower than its static head.

Artesian water.—Artesian water is defined as that portion of the underground water which is under artesian pressure and will rise if encountered by the well or other passage affording an outlet.

Artesian system.—An artesian system is any combination of geologic structures, such as basins, planes, joints, faults, etc., in which waters are confined under artesian pressure.

Artesian basin.—An artesian basin is defined as a basin of porous bedded rock in which, as a result of the synclinal structure the water is confined under artesian pressure.

Artesian slope. An artesian slope is defined as a monoclinal slope of bedded rocks in which water is confined beneath relatively impervious covers owing to the obstruction of its downward passage by the pinching out of the porous beds, by their change from a pervious to an impervious character, by internal friction, or by dikes or other obstructions.

Artesian area.—An artesian area is an area underlain by water under artesian pressure.

Artesian well.—An artesian well is any well in which the water rises under artesian pressure when encountered.

PRODUCTION OF PIG IRON IN 1905.

Twenty States in the Union produced pig iron in 1905. The total production of pig iron in 1905 was 22,992,380 long tons. This is an increase in quantity of 6,495,347 long tons, or over 39 per cent. over the production of 1904. It is an increase in value from $233,025,000 to $382,450,000, amounting to $149,425,000, or 64.12 per cent. The average price per long ton of pig iron increased from $14.13 in 1904 to $16.63 in 1905.

(Stated Meeting, held Thursday, May 10, 1906.)

Observations on the Yellow Modification of Molybdic Acid.

By John Howard Graham.

Department of Chemistry, Central High School, Philadelphia.

[Investigations have shown that the yellow crystalline substance depositing from solutions of ammonium molybdate is of composition $H_2 Mo O_4 . H_2 O$. It was noticed as early as 1876, identified in 1882, and a crystal measurement made in 1903. The following is an extract from the paper as presented.—The Editor.]

Recently, while transferring ammonium molybdate solution from a stock bottle to smaller reagent bottles, I noticed on the bottom of the former, a yellow crystalline incrustation, and there were some loose crystals. There is scarcely a chemist who has not noticed a yellow, yellowish-white or white deposit under similar conditions; but I have never observed one so uniformly yellow and homogenous; and my curiosity led me to the following investigation, the results of which, I think, should prove of interest to everyone handling such solutions.

I removed as much of the crust as I could, crushed it carefully, so as to expose the individual crystals, and then washed with pure water to remove adhering solution. The material was then air-dried. Whenever I had noticed the deposits from solutions of ammonium molybdate, without any good reasons for my doing so, I considered them basic or acid ammonium molybdates, that is, salts in which either ammonia or molybdic acid predominates. With such views in mind, qualitative tests were made with the following results:—

The yellow substance is very sparingly soluble in water, and the aqueous solution decomposes on concentration, affording

a bulky white precipitate, very soluble in ammonia, and this ammoniacal solution deposits on evaporation, white crystals of the molybdates of ammonia, several, because as many kinds of crystals were observed. The white precipitate is undoubtedly molybdic anhydride. Another sample of our material was found insoluble in nitric acid, as might be suspected from the fact that it deposits after continuous standing from solutions strongly acidified with nitric acid. The aqueous solution is decomposed by nitric acid giving the same milky white precipitate which I consider molybdic anhydride. It is very soluble in hydrochloric acid, in fact excessively so, making the solution syrupy. Heated very gently, it yields water; at a higher temperature it turns bluish in color, and if the heating is continued without air access, it becomes yellow and finally white when cold, and shows indications of incipient sublimation. When heated to redness it sublimes completely, the sublimate having all the appearances of pure molybdic anhydride. The results so far could easily have been obtained with any ammonium molybdate. The question suggested itself: Does it contain any ammonia? A rather large sample of the material was boiled with strong caustic soda. I thought I noticed ammonia. Test paper impregnated with mercurous nitrate solution, just turned faintly brown. My conclusions were, that if the substance was a molybdate, it must be of a very acid character. Examined under the objective of a microscope magnifying 85 diameters, the crystals appeared clear, well defined and prismatic. They were so small that I could not make out whether they were of the isometric or the monoclinic system. Later I obtained larger crystals and upon examining them, placed them in the monoclinic system.

With the foregoing facts in hand, literature was searched with the hope that light would be thrown upon the subject. We looked up molybdates, of course, and found nothing that would agree with our substance even qualitatively. A great number of molybdates of ammonia were described by Kämmerer* (1850) and Delafountaine† (1865), the information in many cases being meagre and uncertain. It might be of in-

*Journ. prakt. Chem. Series 1-xlix-445 (1850).
†Journ. prakt. Chem. Series 2-xcv-136 (1865).

terest to note, that Kämmerer estimated molybdic anhydride by reducing with hydrogen to constant weight, and weighing the molybdenum dioxide; also, by heating the salt with air access, adding drops of hydrochloric acid from time to time, and finally weighing the molybdic anhydride. The ammonia was determined by the well-known soda-lime method, the evolved gas being collected in hydrochloric acid and finally weighed as platinum.

The next most logical proceeding was to determine the composition of the substance by estimating water, molybdic anhydride and ammonia. The method used by Kämmerer and suggested by Fresenius, that of reduction by hydrogen, was used. Fresenius says, to use a porcelain boat in a hard glass tube, and that the temperature should not exceed a dull redness. I tried this. The water of crystallization passed over at a very low temperature, and, unless this is increased, no more water comes over. Heating to a dull redness, water resulting from the reduction of the molybdic oxide passes over. At the end of about two hours, the reaction has ceased. The material has suffered various changes of color, yellow to orange, to blue, to black, and to steel grey.

Rammelsberg* states that the contents of the crucible are frequently grey below and brown above. What I obtained was uniformly grey, and the weighings of the supposed molybdenum dioxide gave percentages of molybdenum trioxide as follows:

60.97; 61.12; 60.53; 61.55; 61.95; 61.82; 61.02; 61.64.

Having taken all proper precautions, yet the results were anything but concordant. My attention was next given to the ammonia content. Samples of one gram of material each were thoroughly mixed with finely divided soda-lime, and heated in the usual combustion tube for that purpose. The ammonia was collected in hydrochloric acid and was to have been determined as platinum. From two determinations I obtained such slight traces of the double chloride of platinum and ammonium that I had to consider the ammonia as a negligible trace. I was greatly surprised. I attributed the traces of ammonia to ammonium nitrate occluded in the

*Pogg. Annal. cxxvii-281; Zeitscher. f. anal. Chem. v-203.

crystals, and made the ferrous sulphate and dephenylamine tests for nitric acid. The former was altogether unsuccessful, for the former salt immediately reduced the solution and gave the intense blue due to the lower oxides of molybdenum. With the other reagent I first obtained a blue, due I think to nitrates, and after a time the solution became intensely blue, due again I think to reduction of the tri-oxide of molybdenum. Undoubtedly the ammonia is present in small traces as nitrate. So my yellow substance contains no ammonia in its composition. This directs me upon a new course. As to the water content, two samples of material heated in covered porcelain crucibles, with flames about one inch high and barely touching the bottom, gave results as follows by difference:—

20.07% and 20.03%

The ammonium molybdate solution from which the material was deposited, was purchased from Baker & Adamson and guaranteed pure. There could be present in the yellow substance therefore, no base but ammonia, and no acids other than nitric and molybdic acids. Since ammonia and nitric acid are present only in traces, we can consider them out of the question. The material therefore, should contain nothing but molybdic acid and water, both of which were found and estimated. If the water is present by 20%, there should be 80% of molybdic anhydride. How shall we account for the discrepancy between 61% about, as determined, and 80% theoretical? It could be possible that the contents of the boat were overheated. The supposed molybdenum dioxide did look too gray when compared with the color by which it has been described,—brown to black. It looked exactly like the metal molybdenum itself and it is possible to obtain the metal under these conditions. In order to see if I could get a different result by regulating the temperature more carefully, I heated a sample by stages intending to stop the operation when I obtained constant weight. With a very low flame I obtained a result which calculated for molybdic anhydride gave 85.05%. The height of the flame was then increased so as to have it just touch the tube. The percentage dropped to 78.77. Evidently the crucial point was again overstepped. The following three determinations were made with the flame not quite touching the tube—a Bunsen flame of about 1½

inches. The contents of the boat after cooling were uniformly dull black and homogenous throughout.

Result:—79.93%; 79.73%; 80.00%, the mean of which is 79.93%, and this added to the mean of the water determinations 20.05%;—gives 99.93%, corresponding to the formula $MoO_3.2H_2O$, or $H_2MoO_4.H_2O$.

References to this substance are few, yet they furnish substantially what I have enumerated above. I did not conceive of the substance being a modification of molybdic acid or I should have discovered earlier that the ground had practically been covered by others.

In the year 1876 Junck* observed the yellow deposit. He thought it was a metameric form of molybdic acid resulting from the action of light upon the solution. He made several experiments along this line.

Sergius Kern† took notice of the deposit and published notes concerning it in 1878.

In 1882 Millingk‡ makes mention that the yellow precipitate is $MoO_3.2H_2O$ and gives a meagre description, adding that it is soluble 0.5 gram about in one litre of water.

Parmentier,§ 1882, makes quite a thorough study of it and his observations as to its physical and chemical properties and composition agree quite closely with mine. The results of his analyses are:—

H_2O	19.96	19.95	19.94
MoO_3	80.04	80.05	80.06

Parmentier mentions that the crystals are monoclinic in form and in 1888 Vivier|| confirmed this statement.

It was not until 1903 that the final work upon the substance was done. De Schulten¶ prepared the yellow material according to the methods of Parmentier, acknowledging and confirming all his statements. He puts his solutions aside for years so as to obtain crystals large enough for measurement, and when he obtained some measuring 0.9 mm., 0.8 mm., and

*Zeit. anal. Chem. xv-290.

†Idem xvi-52.

‡Handbuch Gmelin-Kraut 2(2) clxx-1882.

§Comptes Rendus 839, 1882.

||Comp. Rend. cvi-601 (1888).

¶Bulletin French Min. Soc. xxvi-6, 1903.

0.8 mm. respectively along the axes a, b and c, he uses them for this purpose. In his paper reporting the work, he makes a drawing of one of the crystals, which shows the following forms:—

Positive and negative pyramids and orthodomes; two prisms; clino-dome; ortho-and clino-pinacoids and basal plane. The angle between the basal plane and the ortho-pinacoid is 89.19°, making the crystals appear at first glance as though they were cubes. They are clear and the faces are good reflectors.

Yellow molybdic acid is so far an unimportant substance, a mere chemical curiosity, but yet its manner of formation and its occurrence are of interest, and it deserves that we know its properties sufficiently well to be able to identify it.

THE PAN-AMERICAN RAILWAY.

The report of the committee on a railroad connecting North and South America, appointed at the Pan-American Conference in Mexico in 1902, has been submitted to the Pan-American Conference at Rio Janeiro. The committee considers that a railroad 10,400 miles long to connect New York with Buenos Ayres is feasible. Railroads already in existence or projected could be utilized, and it is reckoned that not more than 3700 miles of intercontinental railroad is now specifically provided for. This is divided as follows: Peru, 1200 miles; Ecudor, 450 miles; Colombia, 845 miles; Panama and Central America, 1200 miles. The route proposed is through Mexico into Central America, and along the slope of the Andes into Argentina. Branches to the seacoast, where the road runs through the interior, or into the interior, where the main line follows the coast, are contemplated.—*Iron Age.*

PRODUCTION OF MANGANESE IN 1905.

The production of manganese ores decreased from 11,995 long tons, valued at $116,722, in 1901, to 7,477 long tons, valued at $60,911 in 1902, and to 2,825 long tons, valued at $25,335 in 1903, and increased to 3,146 long tons, valued at $29,466 in 1904, and to 4,118 long tons, valued at $36,214 in 1905.

Section of Photography and Microscopy.

(Stated meeting held Thursday, December 6, 1906.)

Pictorial Composition for Beginners in Photography.*

By J. W. Ridpath, Vice-President of the Section.

Pictorial photography is a very broad subject. It deals with selection of subject, grouping, composition, light and shadow, focusing, making of negative and after treatment of the same, printing and mounting, each being a separate step toward the finished picture. For the present purpose it is intended to speak briefly upon only one branch of the subject.

Pictorial composition is based upon certain well established and generally accepted rules, or general principles, which, although somewhat elastic, are found to be generally observed by artists everywhere. Some say art is subject to no set rules, for its variations are infinite; yet nearly all agree that it has certain general principles. In fact, almost all pleasing pictures, whether paintings, drawings, etchings, photographs, or made by any other process, are found to be based upon some of these rules.

In a short article like this, it is only possible to refer briefly to a few of the more important or fundamental rules of composition, omitting such subjects as lighting, atmosphere, balance, &c. A careful observance of the following nine rules will greatly aid the young photographer in making more pleasing and consequently better pictures:

1. In selecting a subject to photograph there is always a principal object, that which you want a picture of. It should, if possible, be placed to one side of the center and below or above the middle line. In other words, place the principal object in one of the natural quarters of the picture space. The principal object should, if possible, be supplemented by one of lesser importance as a secondary object. If the view contains

*The paper was illustrated with the aid of a large number of lantern photographs appropriately selected to elucidate the points dwelt upon by the speaker.

trees, a position may be selected where a handsome or picturesque tree will occupy a point near the camera, in or near the foreground, as the principal object. This might be supplemented by a small tree of somewhat similar shape in the middle distance. A group of men or women might be supplemented by a group of children placed at a little distance. A church or other important building, in perspective, might be supplemented by a smaller building in another part of the picture.

2. Objects should be few in number and simple in character. A group of two or three trees looks much better than one showing an extensive and elaborate collection of shrubbery. The latter may look beautiful to the eye, but the former will yield a more pleasing picture. One shock of corn, well to the front, with a few others less distinctly shown in the distance, is much better than a number of shocks, equally spaced, at nearly the same distance from the camera. Two or three figures may be satisfactorily grouped, but to make a picturesque group of a dozen will require artistic skill of a high order.

3. In order that your picture may look natural, the surroundings should always be in keeping with the principal object. To illustrate: A lumberman's or huntsman's camp may look well in the forest. A fisherman's boat and nets should be beside water. A wagon loaded with logs might appropriately be coming out of the woods. A farm team should be engaged at some regular farm work, with appropriate surroundings, such as ploughing, hauling grain, raking hay or any other usual farming operation. A quaint stone arch, or rustic bridge, may impress you favorably; if so, you will find that a willow tree, group of shrubbery, or even a bunch of tall weeds, if near the camera, will add greatly to the picturesque effect.

4. The principal forms of composition are three in number. The angular form may be illustrated by drawing an imaginary line diagonally from an upper to a lower opposite corner; thus dividing the picture space into two triangles. The principal object may be advantageously placed in the lower triangle; the secondary object may be placed in the lower half of the upper triangle as middle distance, while the upper half of the upper triangle is occupied by the sky or other background. Sometimes a very handsome angular grouping is effected by placing the principal object in the upper triangle of the picture space with the secondary object in the lower triangle.

5. The pyramidal form of grouping is particularly good for strong objects; being shaped like a mountain it gives an idea of stability. The tall tree, church-tower, a house in perspective or tallest man in a group, occupying a somewhat central and commanding position a little to the right or left of the center of the picture space, might form the basis of a good strong composition.

6. The circular or oval forms are light and graceful and lend themselves naturally to groups of shrubbery or flowers, and still-like objects, curved or radiating forms, are quite plentiful in nature. The dependant branches of the elm and willow, the oval form of the violin, many articles of glass and porcelain, the spray from a fountain, a vase filled with flowers, the oval form of the human face and indeed the long oval of the human frame, are illustrations of this graceful form of composition.

You do not always find objects that compose readily; perhaps the fault is in the objects themselves; perhaps it is the wrong time of day, or time of year; conditions are not always alike. Change your position slightly and look again. If the image on the ground glass is not pleasing, why expose a plate?

7. It is important that the principal lines of the picture be so placed as to enhance its beauty, otherwise they may detract from it. Generally the horizon or sky-line in out-door pictures should be placed about one-third distance from the top or the bottom, not half-way up. In many cases the sky-line is quite important. A gently undulating background with hazy distance, being suitable for peaceful farm scenes. Rugged mountain scenery might appropriately have a saw-tooth or jagged sky-line.

8. All important lines, such as fences, roads, streams, &c., should lead into, not out of, a picture. They should be so placed as to lead the eye unconsciously toward some point of general interest. For the above reason a cross-roads picture is seldom pleasing. If the important lines conform to Hogarth's line of beauty, a graceful double curve, they will greatly enhance the beauty of your picture.

9. Figures, if included in a landscape or other view, should always be appropriate in character, and in keeping with the surroundings. A farmer at work in the fields, dressed in his working clothes, is more picturesque than the same man in his best bib and tucker entertaining company on the front porch.

A hod carrier would look better with a pipe in his mouth, than smoking a cigarette. Two girls in sunbonnets, picking blackberries, might add life to the scene; but two young ladies dressed in silk and lace, wearing ostrich plumes in their hats, would be out of place among blackberry briars. Perhaps there is no more certain way to spoil an otherwise good picture, than to pose your cousin or best girl in the picture center, with nothing to do but stare at the camera. If you must place her in the range of the lens, give her some appropriate employment, such as picking daisies, golden rod, or other wild flowers, but if you value her friendship, don't have her looking at the camera. To do so will probably spoil the composition, and the portrait is almost sure to be disappointing.

Some persons may object that these rules, or general principles, are not practical; that many views cannot be artistically grouped. It is certainly true that many views are quite commonplace, having nothing picturesque in them. In an afternoon's outing the camerist may pass a hundred views, many of which have some attractiveness; but only one or two appeal to him. While you cannot move the wayside cottage or trees, you can move the camera. Select the most important object and give it a strong place in the picture space, a little out of the center. Select a few objects, not too many, as accessories; most views contain too much. Try to find a suitable foreground. Move a little nearer or farther away; to the right or left; raise or lower your camera. While the principal object should occupy a strong place, the view should be considered as a whole, unity or oneness being all important. Examine the image on the ground glass and select the best viewpoint. If you spend a little time intelligently studying the scene, the chances are that you will secure a much better picture than you could by a "hit or miss" method. Remember that one good picture is worth more than ten poor ones.

The Franklin Institute.

Proceedings of the Stated Meeting held Wednesday, December 19th, 1906.

HALL OF THE INSTITUTE,
Philadelphia, December 19, 1906.

President JOHN BIRKINBINE in the chair.

Present, twenty-five members.

Additions to membership since last report, four.

Mr. Birkinbine made the following remarks in view of his contemplated retirement from the office of President, viz:

"To the Members of the Franklin Institute:

"In accepting the re-election of President last January, I expressed the intention to retire at the close of the Institute year, and therefore my name will not be presented for re-nomination.

"For ten successive years you have bestowed on me the highest honors which the Institute can offer a member, and this opportunity is taken to express warm appreciation of your confidence and support.

"The first President of the Institute served for 16 years, and the second for 14 years, but with these exceptions no one has presided over the Institute for a longer period than myself; a compliment of which I am justly proud.

"The decision to withhold my name as a candidate for President, is not due to unwillingness to perform the duties imposed by the office, nor to waning interest in the work which the Institute seeks to accomplish, nor to failure to appreciate the high honor of presiding over an organization whose fame is world wide, and which for eighty-two years has striven to advance science and the arts. On the contrary, if the matter is considered from a strictly selfish standpoint, it would be gratifying to continue in office.

"While no duty has been intentionally avoided in the decade just closing, the office demands from the President attention difficult to give by one upon whom active engineering duties make claims, especially as professional work requires repeated and extended absences from Philadelphia.

"Experience has demonstrated the importance of having the Institute presided over by one who could personally oversee the many details of its work, and by his presence inspire activity, hence, I believe, the action taken will be to the advantage of the Institute.

"A retrospect of what has been accomplished by the Franklin Institute in the past ten years, is gratifying, but the realization that it has been impossible to secure funds sufficient to insure rehabilitation of the Institute is a source of regret to myself, as it was to my predecessors. However, indications are now more favorable towards securing a new building and advanced facilities than ever before, and with the active support of all members this may become an assured fact during the administration of my successor.

"That an organization which has accomplished so much; which has rendered gratuitous service to city, state and nation, which has advanced so many inventions; which is honored in every country; which has an unexcelled technical library, and which has educated in its schools thousands who were unable to secure the advantage of technical instruction elsewhere, should be hampered in its efforts by insufficient funds, seems strange in the days when millions are devoted to younger, but not more useful organizations, and to the establishment of libraries far inferior to that of the Franklin Institute.

"In relinquishing the responsibilities and honor of the presidency, I urge upon all members and friends of the Institute united and persistent effort to secure sufficient endowment to erect, equip and care for a build-

ing which will permit of the Franklin Institute maintaining its work, free from the discouragements which have beset its management.

"Those who have served as my colleagues on the Board of Managers, have expressed a desire that I should continue a member thereof, and if this is your wish it will be my pleasure to support my successor and render service as a manager as a slight return for the honor which has been conferred on me."

At the close of the President's remarks the following preamble and resolution, offered by Prof. Lewis M. Haupt, and duly seconded, were unanimously adopted, viz:

"WHEREAS, The Institute learns with regret of the declination of its President for good and sufficient reasons to consent to a re-nomination for the ensuing year. It is therefore

"*Resolved,* That this meeting expresses its high sense of appreciation of the services rendered by Mr. John Birkinbine during the past ten years as an active and efficient President of this Institute.

"*Resolved,* Further, that a copy of above resolution be sent to the President as an expression of the good-will and appreciation of the members for the services rendered."

Prof. Haupt thereupon read a paper on "The Chesapeake and Delaware Canal," fully illustrated by means of lantern slides, in which he strongly advocated the importance of improving this water-way, in the interests of commerce.

The paper was discussed by Messrs. James Christie, Louis E. Levy, Henry F. Colvin and the author.

(The paper is referred for publication). The speaker received the thanks of the meeting for his able and interesting communication.

The following nominations for officers, managers and committeemen were made, to be voted for at the Annual Election to be held on Wednesday, January 16, 1907, between the hours of 4 and 8 o'clock p. m., to wit:—

For President	(to serve one year)	WALTON CLARK.
" *Vice-President*	(" three years)	HENRY HOWSON.
" *Secretary*	(" one year)	WM. H. WAHL.
" *Treasurer*	(" ")	SAMUEL SARTAIN *
" *Auditor*	(" three years)	SAMUEL P. SADTLER.

For *Managers* (to serve three years).

STEPHEN GREENE, CHARLES A. HEXAMER, ALEX. KRUMBHAAR, ALFRED C. HARRISON, HENRY R. HEYL, WALTER WOOD, JOHN BIRKINBINE.

For *Managers* (to serve one year).

OTTO W. SCHAUM, E. H. SANBORN.

For *the Committee on Science and the Arts* (to serve three years).

JAMES CHRISTIE, G. H. CLAMER, J. LOGAN FITTS, RICHARD W. GILPIN, WM. O. GRIGGS, FRANCIS HEAD, CHARLES A. HEXAMER, WALDEMAR LEE, JACOB Y. M'CONNELL, J. W. RIDPATH, LINO F. RONDINELLA, ARTHUR J. ROWLAND, SAMUEL SARTAIN,* FRANK SHUMAN, T. CARPENTER SMITH, THOMAS SPENCER, WILLIAM H. THORNE, J. C. TRAUTWINE, JR., WILHELM VOGT, URBANE C. WANNER.

Adjourned.

WM. H. WAHL, *Secretary.*

*Since deceased.

JOURNAL

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FOR THE PROMOTION OF THE MECHANIC ARTS

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THE FRANKLIN INSTITUTE.

(*Presented at the stated meeting, December 19th, 1906*)

The Chesapeake and Delaware Canal.

BY LEWIS M. HAUPT, A.M.; Sc.D.

Professor of Civil Engineering in the Franklin Institute.

Mr. President and Members of the Institute:

The Franklin Institute as well as the various trade and commercial bodies of this city and of the nation have, for many years been importuning the General Government to extend the facilities for our internal commerce, over the waterways of the country, with but slight results. Other and far more potent influences have dominated legislation and retarded or prevented the passage of enabling acts to open, enlarge or emancipate our canal systems. A crisis has been reached and a return to the waterway is compulsory, because of its greater capacity and economy.

EARLY CANALS.

Three years after the inauguration of President Washington the first canal was built in the State of Massachusetts, at South Hadley, around the falls of the Connecticut River, which were fifty feet in height. It was two miles long, had five locks and passed through a cut forty feet in depth.

Among the earliest charters granted was that of the Dismal Swamp Canal, in Virginia, which was designed to be only 32 feet wide, and to float vessels of 3 feet draught, for the purpose of getting timber from the swamp. In 1816 the company was authorized to raise $50,000 by lottery to enlarge the locks, which were 90x32x4 feet in dimensions.

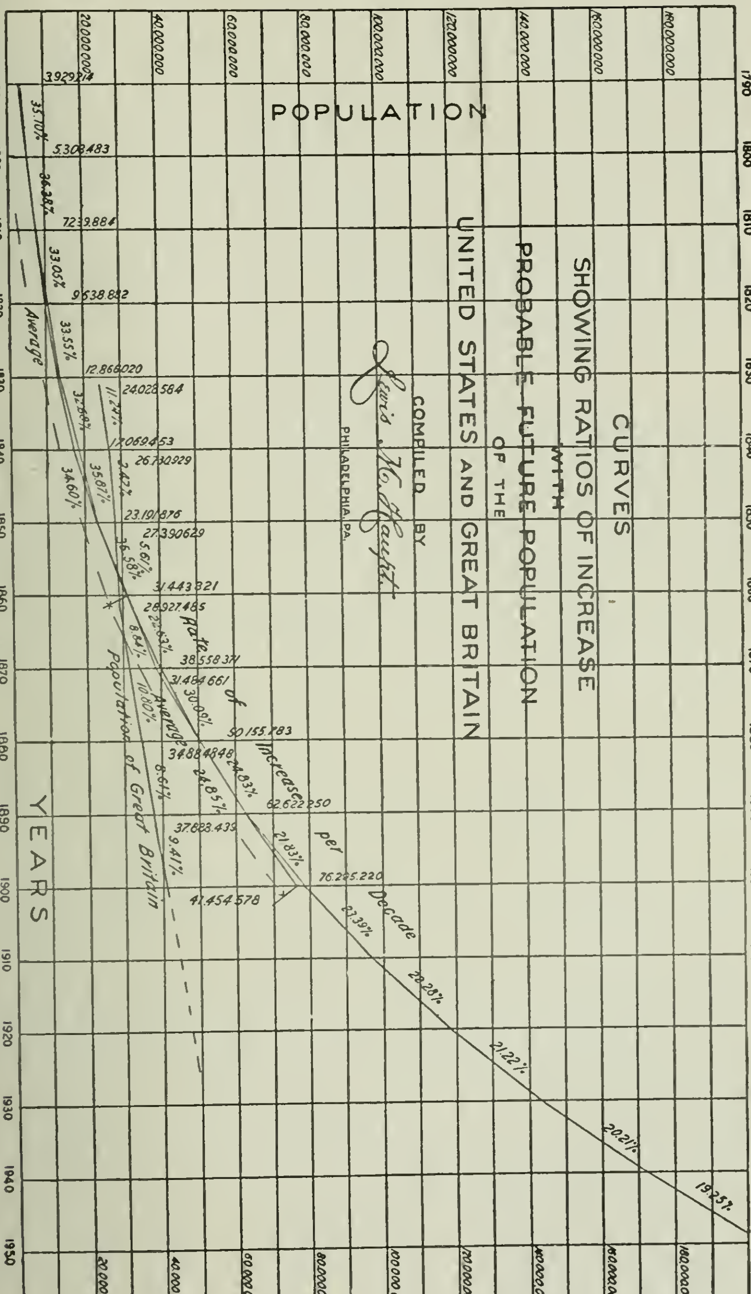
Similar recourse was authorized by the State of Pennsylvania to complete the work on the Union Canal, which was designed to connect Lake Erie with Tidewater, and after having contributed $300.000 to the company the State, in 1821, guaranteed the interest and granted a monopoly of lotteries.

Thus sustained, work was resumed in 1821, and the link between the Susquehanna and the Schuylkill Rivers was completed in 1827, or 37 after its beginning and 65 years after the first survey.

These few facts are submitted to illustrate the difficulties encountered at the beginning of the canal epoch, when there were no avenues of communication save a few earth roads and the natural watercourses. During these forty years (1790-1830) the population, which is the basis of internal communications, increased from about 4.000.000 to nearly 13.000.000 and the canal mileage at the end of 1834 was reported to be 2617.89 miles.

CHEAP FUEL THE ISSUE.

The greatest economic stimulus was given to canals by the discovery of hard coal on the Mauch Chunk (Bear) Mountain, in 1792, by one Philip Ginter, who took a sample to Col. Jacob Weiss, and he, in turn, submitted it to Michael Hillegas, the first Treasurer of the United States, as well as to John Nicholson, and Chas. Cist, a printer, all of Philadelphia. About the beginning of 1792 these parties formed the "Lehigh Coal-Mine Company," and took up from 8,000 to 10.000 acres of


CURVES
SHOWING RATIOS OF INCREASE
WITH
PROBABLE FUTURE POPULATION
OF THE
UNITED STATES AND GREAT BRITAIN
COMPILED BY
Lewis M. Haupt
PHILADELPHIA, PA.
POPULATION
YEARS
Rate of Increase per Decade
Population of Great Britain
Average

lands, but the difficulties of securing transportation compelled them to abandon their enterprise. At that time hard wood was selling in the city at $13 per cord. It was found to cost $13.50 to haul a "load" of coal by wagon from the quarry to Philadelphia, so that it could not compete profitably with hickory, and the Schuylkill and Lehigh Navigation Companies became a necessity. These canals, together with the Erie, the Chesapeake & Delaware, the Delaware & Hudson and many others were in operation by 1829.

THE RAILROAD EPOCH.

But canals could not be built where water was not available and the rapid increase and distribution of population, coupled with the invention of the locomotive gave a great impetus to the construction of railways, which have now become the dominant transportation interest in the country. From about 1,000 miles in 1835, they have expanded to 220,028.44 miles at the end of June, 1906. This is exclusive of sidings and yard trackage.

ENORMOUS POPULAR INVESTMENTS IN CORPORATE COMPANIES.

The total liabilities in bonds, stocks, &c., amount to $16,-219,573,845. The gross receipts to $2,319,760,030, which is 14% of the capital. It represents the annual tolls for freight, express, passenger and other service paid by the patrons of the system. The total expenses for maintenance and operation are $1,532,163,153, leaving 33% for the payment of interests, rents, taxes and dividends, so that there results an average dividend on this enormous capital of only about 3.65% on bonds and 3.02% on the capital stock. Some roads pay nothing. Those which pay the best are located along the water-courses where there is the cheapest kind of competition. Hence the development of waterways cannot injure the shareholders of railroad securities.

During the past year after paying 590 millions for betterments and 230 millions for dividends, the railroads had a credit balance of $100,428,707.

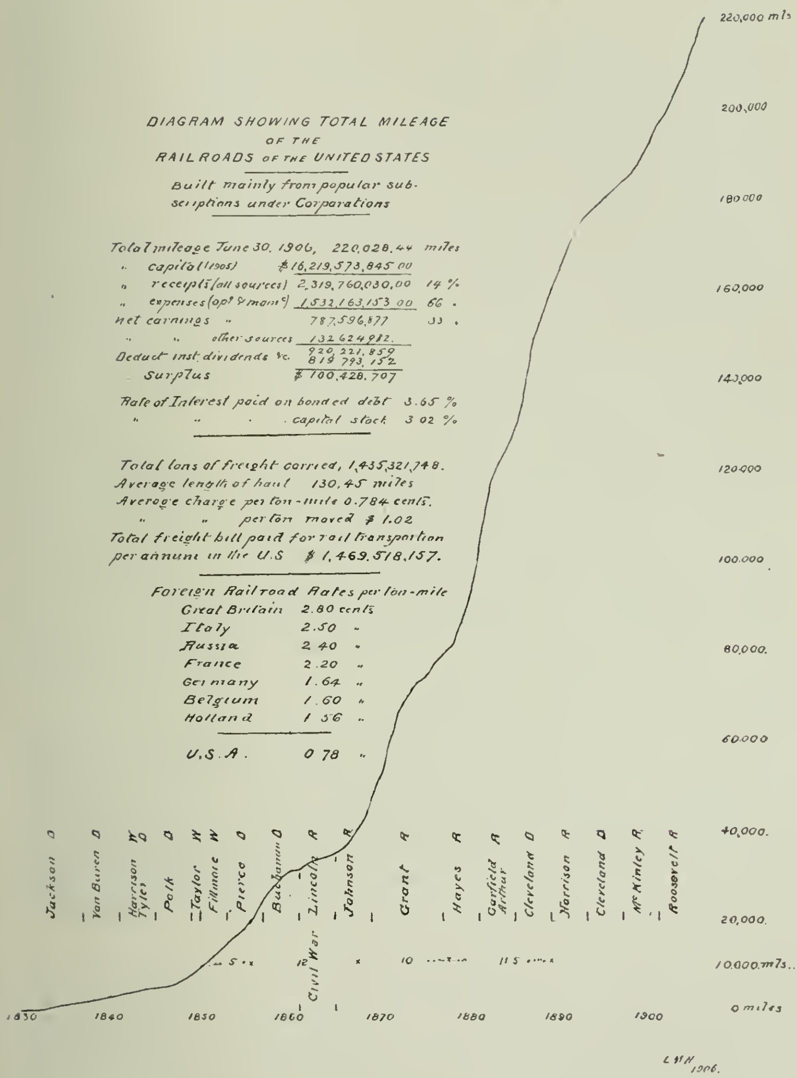


DIAGRAM SHOWING TOTAL MILEAGE
OF THE
RAILROADS OF THE UNITED STATES
Built mainly from popular subscriptions under Corporations
Total mileage June 30. 1906, 220,028.44 miles
" capital (1905) $16,219,573,845 00
" receipts (all sources) 2,319,760,030.00 14 %
" expenses (opt & maint) 1,532,163,153 00 66 "
net earnings " 787,596,877 33 "
" " other sources 132 624 982.
Deduct int. dividends &c. 920,221,859
819 793,152
Surplus $ 100,428,707
Rate of Interest paid on bonded debt 3.65 %
" " " capital stock 3 02 %
Total tons of freight carried, 1,435,321,748.
Average length of haul 130.45 miles
Average charge per ton-mile 0.784 cents.
" " per ton moved $ 1.02
Total freight bill paid for rail transportation per annum in the U.S $ 1,469,518,157.
Foreign Railroad Rates per ton-mile
Great Britain 2.80 cents
Italy 2.50 "
Russia 2 40 "
France 2.20 "
Germany 1.64 "
Belgium 1.60 "
Holland 1 56 "
U.S.A. 0 78 "
220,000 mls
200,000
180 000
160,000
140,000
120 000
100.000
80,000.
60.000
40,000.
20,000.
10.000 mls..
0 miles
Jackson D
Van Buren D
Harrison Tyler
Polk D
Taylor Fillmore
Pierce D
Buchanan D
Lincoln R
Johnson R
Grant R
Hayes R
Garfield Arthur R
Cleveland D
Harrison R
Cleveland D
McKinley R
Roosevelt R
Civil War
1830
1840
1850
1860
1870
1880
1890
1900
L.M.H. 1906.

The total number of tons carried was 1,435,321,748,* and the average haul was only 130.45 miles. The average charge per ton-mile was 0.784 cents. This makes the average charge for each ton moved on the railroad $1.02. This enormously potent system exists by virtue of the confidence which the people of the United States, aided also by foreign capital, have placed in the integrity of the masters of transportation, who have gradually consolidated the individual and disjointed enterprises into great trunk lines stretching across the continent.

Some of these lines were subsidized by the grants of extensive tracts of land or by loans from the public treasury, but the Government has entrusted their management and operation to the corporations who have developed or purchased the control, excepting in case of war, when some of them were seized temporarily for strategic purposes. That the policy of thus encouraging local, private and corporate initiative was wise, the results have amply proven.

It cannot be claimed that the low rates on American railroads are in consequence of improved water competition, since there is practically none, with the exception of the Great Lakes, where, although the rates are the lowest, the railroads receive a much greater revenue per mile than in any other portion of the country. In group II (New York to Md. inc.) the rate is 0.667 cents and the receipts from freight per mile is $14,010, which is nearly double that of New England (I) and three times that of group IV.

On the other hand, the European railways, where there are well developed competing waterways, are enabled to charge from three to four times as much for an equivalent service. Thus in Great Britain the average charge is 2.2 cents; in Italy, 2.5; in Russia, it is 2.2; in France, 2.2; Germany, 1.64; Belgium, 1.60, and in Holland, 1.58, while at home it is only 0.78.

CONGESTION.

The curve of progress, in this matter of overland transportation, indicates that the end is not yet, but the experience of the past year serves to emphasize the fact that the railroads

*5150 square miles, one foot deep, when reduced to the shipping ton, or enough to blanket the entire State of Connecticut.

have limitations and that they are unable to handle the traffic in small units, especially where large quantities of low grade freights are required to keep the wheels of industry in motion, or even to provide the requisite amount of food and fuel to the populous centers.

That a crisis has been reached due to the failure of the carriers to handle the products of the soil and their inability to secure the necessary terminal facilities will be apparent from a few extracts taken from the daily press, as follows:—

"Orders have been issued by the N. Y. Central Lines west of Buffalo, instructing all agents to cease soliciting business, as the roads are unable to handle what comes to them naturally, but to spend their time in hunting up cars. * * * Never in the history of Western roads was the freight congestion so great as now. It was reported that the Northern Pacific road has at least 10,000 cars which it is unable to move."

In Pittsburg the shortage of cars was recently reported to be 5000. Bradstreet says: "The really serious cause of complaint is the practically country-wide congestion in railway traffic which affects grain movement, collections and retail sales in the Northwest, delays delivery of badly needed coal supplies in the entire West, interferes with the movement of cotton to market in the South and hampers manufacturing operations in the iron and steel, textile, lumber and other trades.

An official of the Pennsylvania Railroad said: "It is almost impossible to say what car shortage exists on account of the daily increase in the amount of traffic. The demand for more cars comes from every part of our system. The general belief is that the business will increase during the next year."

In the meantime the Interstate Commerce Commission is investigating the alleged car shortage and it is reported by Commissioner Lane that the agents in the Northwest state that the roads in the wheat belt are discriminating against grain and accepting other traffic. " * * * There are millions of tons of freight awaiting shipment at the present time, which the railroads confess themselves unable properly to handle. Whether there is an actual car shortage or not is a question to be determined, but that there is fault to be found with the manner in which cars are used seems to be generally conceded by all traffic men."

Later dispatches, dated from North Dakota, Dec. 16, report that "A frightful condition exists owing to scarcity of fuel. Several persons have frozen to death as a result of the railroads inability to furnish cars for the shipment of coal and wood. Two entire families perished. In scores of places no coal can be bought. Farmers are making no efforts to ship their wheat, which is left lying under the snow; the cry is for

fuel. Hay and straw are being burned, as well as fences and outbuildings, even the grain in the elevators is threatened, while the railroads and common roads are blocked with snow."

Dec. 17.—Nebraska towns are out of fuel and the price has risen to $18 and $20 a ton. In Western Kentucky there is a coal famine, and oil is scarce in Phoenix, Arizona, so that the electric and gas companies have been shut down.

The Interstate Railroad Commission is startled at the reports which are coming in from the West.

To meet this condition some roads are placing millions of dollars in additional rolling stock, and heavier locomotives, but after all, it comes back to the inadequate facilities for unloading these units at the terminals. President Hill, of the Great Northern Railroad, has very truly said that "To-day the entire country is suffering from want of transportation facilities to move its business without unreasonable delay. The prevailing idea with the public is that the railways are short of cars, while the facts are that the shortage is in the tracks and terminals to provide a greater opportunity for the movement of the cars."

Hence to increase cars without a corresponding increase in yards and storage capacity, merely aggravates the evil and increases the cost. In fact, a recent report of one of our trunk lines stated that its operating expenses had been increased 25% in the year because of the lack of facilities, and the difficulty of securing them is rapidly increasing. It is admitted that suitable terminals cannot be had in the vicinity of New York harbor to-day for $150,000,000.

COLD AND FAMINE.

Thus while our surplus food supplies are bottled up on the farm, there comes a far cry from the older civilizations, of distress, poverty, and crime, terminating in death, because of the absence of food.

Twenty millions of Russians affected by famine and parents selling their *daughters* to Mohammedans for $50 for the worst kind of servitude. Children whose ages range from 12 to 17 years are thus sold for food. The "hunger typhus" fever, resulting from starvation, is epidemic in Kazan.

Fifteen millions of Chinese are reported to be suffering from flood, fever and famine.

A CHANGE OF POLICY DEMANDED.

The remedy for these economic and social problems involves a radical change of policy. The railroads have in the past absorbed many of the canals and waterways which were regarded as dangerous rivals and have undertaken to handle the crude, freights of low value, by mechanical devices, involving at least three times the cost of the water-borne traffic. They have leased canals, at high rates of interest, merely to keep the traffic on the rails and have compelled manufacturers to pay much higher rates for coal, ores, lumber and other materials.

It would seem that the time had arrived when the traffic should be segregated to the cheapest, most capacious and quickest conveyors for the bulky materials, that the higher class freights may have the right-of-way and there may be less congestion in the yards and terminals. To this end all through freights for export or coastwise delivery, should be shipped at the nearest tidewater terminals and not be hauled into the great cities at all where the miles of cars greatly add to the dangers and delays of municipal traffic.

Thus the neglected condition of our internal and coastwise waterways is being forced upon the attention of the public as a necessary aid to the traffic of the country. Although about $400,000,000 have been expended upon these works since 1822 by the Government, the projects already approved by Congress, are estimated to cost over $400,000,000 more to meet the demands of the present day, and it is now difficult to secure the passage of a River and Harbor bill, even every three years. Legislation is blocked so subtly that it is next to impossible to prevent it. Some of the most important measures for the opening of the rivers and canals of the country, even where no expense is involved, are delayed for a score or more of years. Yet the plea is made that the funds can be applied to better advantage than for internal commerce. In this great and prosperous country, committed to the policy of arbitration and deriving all its revenues from the avocations of peace, the demand arises continually for over seventy per cent. of the total appropriations for destruction and waste, while a mere bagatelle is applied to construction and economy, the administrative, judicial and legislative de-

partment. Is this good business? If not, then it is neither good policy nor good government.

THE NAVAL BUDGET.

In a recent dispatch from Washington to the press it was stated that the nation expends over $100,000,000 annually for a navy which is in a low state of efficiency and that the officers are too old, as well as the vessels, while one of the "ancient," and hence experienced, mariners in a public address, delivered not long since, admitted that the battleships were obsolete and the cruisers of little use. Another officer says that the life of the heavy guns is limited to about sixty rounds, which could be fired in an hour and a half, so that a new system of guns and of firing them is recommended. In the meantime it is reported that the situation in Japan is becoming threatening over the inability or unwillingness of this country to educate the Japanese children in the schools of the Pacific Coast, and that the Philippines and Hawaii, as well as the Pacific seaboard need to be protected by larger fleets, and the Panama Canal to be pushed rapidly to completion so as to be ready for any emergencies. Which means larger appropriations for these great floating war engines, which may be scuttled in a moment by a stray shot or uncharted rock.

There are some striking figures in the bulletin just issued from the Treasury Department for the expenses of the coming year, as follows:—

Out of a total approaching 700,000,000 dollars there is to be applied to Government expenditures (Legislative, Executive, Judicial and Foreign intercourse) nearly $40,000,000; to Miscellaneous and Permanent appropriations, $209,000,000, and to Public Works, $95,000,000. On the other hand, for the elements of war and its concomitant evils there are the items of

War	$ 79,950,102
Navy	115,444,950
Indians	7,970,160
Pension	138,243,000
Making a total of	$341,608,212

Agriculture and Internal Commerce, which are the chief

sources of the wealth and revenue, have the smallest appropriations, and they are the most uncertain and difficult to secure.

Under these conditions, therefore, it is manifest that the country cannot expect any very rapid development to result from the exercise of its jurisdiction over the waterways, and this obstructive system of governmental control and patronage stands out in glaring contrast with the enormous expansion of the less profitable rail transportation, now so generally useful, but already outgrown by the productive industries of the nation, which demand greater relief.

A MANIFEST REMEDY.

The remedy must lie in the return to the ante-bellum policy of permitting any section, State or corporation to undertake its own improvements, whenever there is an apparent need. In many instances this would have been done had it not been necessary first to secure a special act from Congress. The greatest and most beneficent canal in the world to-day as to tonnage was opposed by the Government in 1839, when the State of Michigan had provided the means to dig a canal around the falls of the Sault Ste Marie, but the United States declined to grant a right-of-way through its military reservation. This opposition of the military arm continued until 1852, when the State finally undertook the work, and subsequently, after its utility was demonstrated, conveyed it to the Government.

THE KEYSTONE OF THE COASTWISE SYSTEM.

Many other instances might be cited of works which have been retarded for a generation, but suffice it to refer to the case of the Chesapeake & Delaware Canal, the enlargement of which was urged by a Convention, held in Baltimore as early as 1871, when it was recommended that, "If found to be practicable, desirable and valuable to the great interest of the country, that the said ship canal be constructed."

On the 11th of March, 1872, the House of Representatives called on the Secretary of War for a report on this project, but it was not until 1878 that an appropriation was made for the surveys upon which to base an opinion. Preliminary surveys

were made in 1879, accompanied by a report covering the lower routes and requiring further examinations into those at the northern end of the Peninsula, where it was narrowest. These were made and a report submitted in 1883, recommending that a mixed commission should be appointed "to consider and to report its opinion as to which of the various routes surveyed will afford the greatest protection in case of war, and the greatest facilities to commerce."

In 1894, eleven years later, such a commission was appointed and submitted its report to the effect that "THIS BOARD DETERMINES THE MOST FEASIBLE ROUTE FOR THE CONSTRUC-

The "Deep cut," looking east (3 miles).

TION OF THE CHESAPEAKE AND DELAWARE CANAL TO BE THE BACK CREEK ROUTE, WHICH IS SUBSTANTIALLY LOCATED UPON THE LINE OF THE EXISTING CHESAPEAKE AND DELAWARE CANAL. THIS ROUTE WILL BE BEST ADAPTED FOR NATIONAL DEFENSE AND WILL GIVE THE GREATEST FACILITY TO COMMERCE." So that after twenty-three years the Memorial of the National Commercial Convention was at length answered, and the best route was determined upon, but again local in-

terests intervened to prevent further progress for a period of twelve more years, resulting in the appointment of another mixed commission to pass upon the findings of the former board as to the relative advantages of the two most northerly routes. However emphatically it may endorse the findings of its predecessors it is feared that in view of the shortness of the session (1906-7) no definite action may be taken, as the River and Harbor bill is practically completed and will carry an exceptionally large aggregate, but it is doubtful if any item on the bill would be of greater general benefit to the entire country, as a measure of peace or war, than one authorizing the immediate construction of an open, capacious and free canal across the neck of the Chesapeake and Delaware Peninsula on the best practicable route, and making an appropriation therefor.

The basis for this confident assertion will be seen from the following extracts presented by the Trades League of Philadelphia to the Chesapeake and Delaware Canal Commission (of which General Felix Agnus is the Chairman, and Major C. A. F. Flagler, U. S. A., and Lieutenant Frank Chambers, U. S. N., are members,) at a hearing held in the Bourse, on the 27th day of September, 1906, when the following argument, in part, was respectfully submitted:—

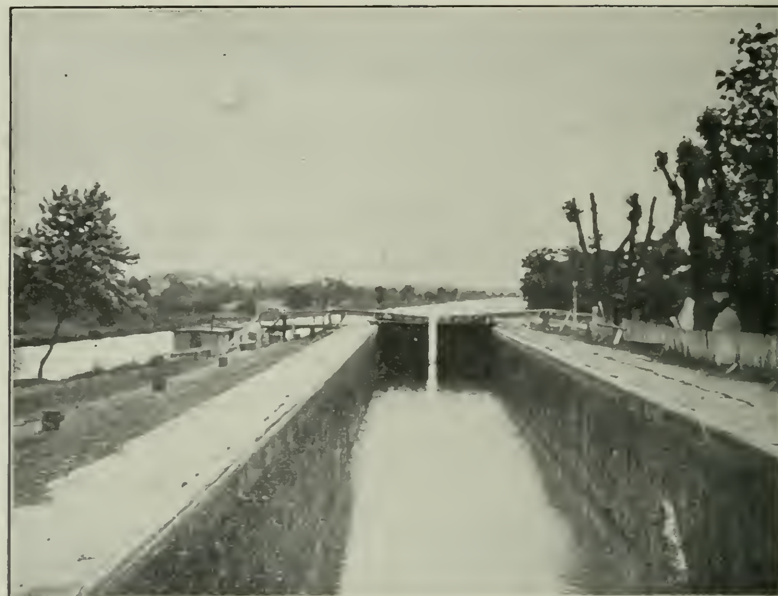
ARGUMENT OF THE TRADES LEAGUE OF PHILADELPHIA.

1. The Chesapeake and Delaware Canal is a vital factor in coast defense, which may be secured for less than the price of one battleship, while it would at least double the efficiency of an entire fleet.

2. The absence of this connection between these two arms of the sea, during the War of 1812, cost the Government its National Capital and many valuable records, worth far more than the estimated cost of the proposed enlargement, ($8,000,000).

3. The existence of the present restricted waterway, opened in 1819, saved the National Capital during the Civil War, when the overland communications were interrupted.

4. The high tariffs consequent upon its limited size, are a serious embargo upon interstate commerce, since it can pass



St. George's Lock (lower gates opening), only 220 feet long, 24 feet wide and 10 feet deep.

Towing lumber schooner by mule team.

barely three per cent. of the coastwise vessels, which have outgrown its antiquated dimensions.

5. The economies effected by the enlarged canal would

Towing 600-foot raft through "Deep Cut."

cover the cost of the work in a very few years, while such a canal would also operate as an efficient natural rate regulator and at the same time develop a very much larger tonnage of higher class freights for the overland carriers, thus adding

largely to their revenues. This paradoxical result has been demonstrated fully by all the great canals and cheapest waterways in the world.

6. There is a greater amount of tonnage in sight to-day (50,000,000 tons), on these two bays and their tributary waters, than now traverses any of the great canals of the world. Nearly all of this is compelled to round the capes at great expense and risk.

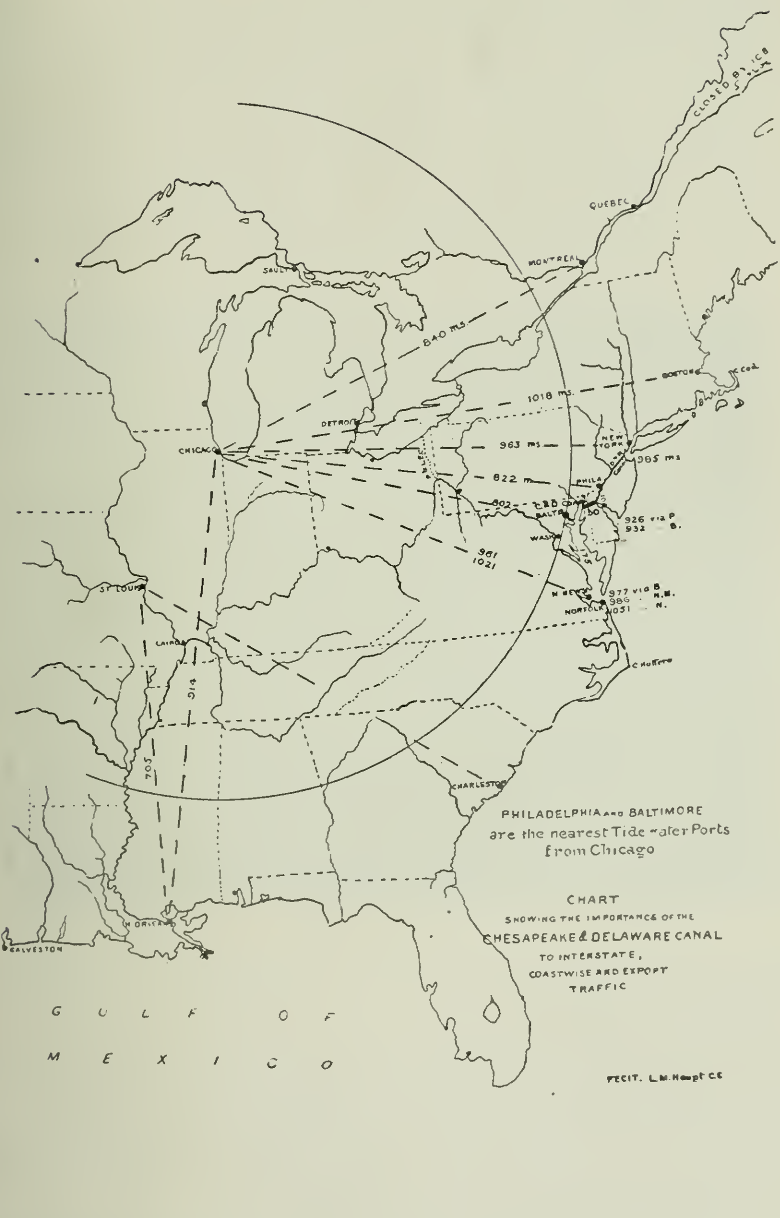
7. Industries and manufactures from New England to the Gulf of Mexico would be benefitted by the larger and cheaper shipments of fuel from the Cumberland and West Virginia fields, made through the Bay ports, if this canal was made large enough to pass ocean barges.

8. The differentials and exceptional facilities enjoyed by the Port of Baltimore, will attract the trade of the great West and draw vessels in ballast from northern ports through this short canal to that harbor.

9. The great necessity for this waterway has been under consideration for more than a century and its enlargement has been vigorously urged by commercial and trade bodies, by scientific and learned societies, by national boards and conventions and by officers and boards of the Army and Navy for many years.

10. Its superior geographical position and physical advantages have been attested by the unanimous reports of the many boards of engineers, both mixed and military, which have reported on the various solutions of this much mooted problem, and the conclusion has been reached, that, all things considered, the route which lies in the track of coastwise commerce and within the range of the defense is the best.

11. It has apparently not gotten beyond the stage of good resolutions, surveys and reports, by Congress, because of the excessive demand for National appropriations for other and less profitable purposes; yet it would seem from the above considerations, that there is no possible improvement, within the Federal domain, which would be more beneficial to a larger number of interests, both in peace and war, at so small an outlay as this; and as a business proposition it has no parallel, either in utility or economy, in any part of the globe, cost alone considered.


PHILADELPHIA AND BALTIMORE
are the nearest Tide-water Ports
from Chicago
CHART
SHOWING THE IMPORTANCE OF THE
CHESAPEAKE & DELAWARE CANAL
TO INTERSTATE,
COASTWISE AND EXPORT
TRAFFIC
FECIT. L.M. Haupt C.E.
GULF OF MEXICO
CHICAGO
DETROIT
QUEBEC
MONTREAL
BOSTON
NEW YORK
PHILA
BALTO
WASH
NORFOLK
CHARLESTON
ST LOUIS
CAIRO
N ORLEANS
GALVESTON
SAULT
840 ms.
1018 ms.
963 ms
822 m
985 ms
926 via P
932 B.
977 via B
986 R.M.
1051 N.
914
705

12. The U. S. Engineer's estimate of 1883 for the Chesapeake and Delaware route, of $7,605,471, is composed of two parts, of which $4,388,797 is for the canal proper and the balance $3,216,674 is for the approaches, which are beyond the jurisdiction of the canal company, so that it has been unwilling to expend a large sum to increase the capacity of its portion of the waterway without first securing some assurance of cooperation on the part of the Government to the approaches.

13. In brief, the Chesapeake and Delaware Canal Route is the shortest, cheapest, most navigable, least obstructed by ice

Towing coal barge to Baltimore

or bridges, most practicable to maintain and is immediately available for traffic.

Why should the Government expend on other routes many millions more than it would cost to enlarge the Chesapeake and Delaware Canal, with its superior advantages, and thus destroy the value of the property in which it is a large joint owner ?

In further elaboration of the condensed theses giving reasons why the present Chesapeake and Delaware route was the

better, some illustrations from the history of the country were cited as to the effects due to the absence of such a water communication during the War of 1812, and the benefits derived from its existence during the Civil War, as follows:

It is well known that our Atlantic and Gulf coast cities are within easy steaming range of the foreign naval bases at Halifax, Bermuda, Kingston, Saint Lucia, and other places, and that the most vulnerable points of our seaboard are the various bays and sounds which indent the coast. To protect these

Delaware R. R. drawbridge

efficiently, a very large navy is necessary unless we can operate upon interior short bases.

In 1812 the British fleet forced the *"Constellation"* to take refuge in Norfolk harbor, where she remained during the war. The mouth of the Delaware was blockaded by three vessels, while four more of the enemies ships cut off the coast trade between New England and the Southern States. The lights were extinguished and the people of the coast realized their defenseless positon. The Eastern Shore was pillaged by Admiral Warren, while Cockburn attacked and burned the villages

at the head of the Chesapeake Bay and destroyed Cecil Furnace where our guns were cast. Norfolk and Hampton were also attacked and the cities of Richmond and Washington threatened.

In the North the "*Decatur*" was penned in New York harbor, and by September, 1814, all of Maine east of the Penobscot had been captured and annexed to New Brunswick. Nantucket, reduced to famine, capitulated to remain neutral, if given clothes and provisions. Castine, Belfast, Hampden,

Towing five barges of cross ties for P. R. R.

Machias and Bangor yielded to a superior force. Many towns paid a ransom. Stonington was destroyed and New England was greatly alarmed, and ready to secede. Cockburn and Lord Ross then returned to the Chesapeake and on the 24th day of August, 1814, destroyed the National Capital and many of its records by fire.

Our thousands of coasters and ten thousands of sailors were driven from the seas, and the coastwise traffic was forced to take the inland route over mud roads in the so-called "schooners," of which there were about 4,000 by the end of the

war. When the roads were passable it required 26 days to cover the distance from Boston to Baltimore and 33 days more to Augusta, Ga., making two months in all. Provisions rapidly rose in price, money became extremely scarce, the National Bank failed, and the country was in desperate strait when the news was received of the signing of the Treaty of Ghent. These events served to impress upon the country the necessity of connecting our coastwise waterways by navigable canals and led to the completion of the Chesapeake and Delaware Canal as the greatest and best work of the times. Its enlargement is even more necessary to-day to meet the urgent demands of coastwise commerce and national defense.

In 1892 General Craighill, ex-Chief of Engineers, wrote: "If a connection be made between the two bays north of Baltimore, it would be much better to have it by an enlargement of the existing canal, to the construction of which the United States has already contributed, rather than to open a parallel to it so near as the Sassafras route, which has been strongly advocated by others interested in it."

Still later, in 1898, he wrote: "My opinion is very decided that the system of coastwise canals should be enlarged so as to be available for use by the Navy and vessels of commerce, especially in time of war, and for this and other reasons, should be controlled by the United States." Thus this distinguished officer urged the enlargement and emancipation of this particular canal for commerce and national defense. Is it necessary for this nation to engage in a war to convince Congress of the necessity of enlarging and emancipating our interstate channels from tolls in behalf of commerce, domestic trade and rate regulation?

Again the city of Baltimore took official action by the passage of a resolution, March 17th, 1894, calling upon the Engineer of its Harbor Board for a report upon the Maryland and Delaware Ship Canal, which he submitted on the 26th of of the same month, and in which he states, *inter alia*, "Studies have reduced the available routes to three. * * * As the same advantages and disadvantages pertain to each of the northern routes, it would appear that if either be adopted it should be the less costly. * * * The importance of a shorter route to the ocean for the coastwise and trans-Atlantic

commerce of Baltimore is too obvious to require argument; it is also of importance in an equal degree to the large territories of the Northwest, which find here the nearest point for the shipment of their products to Europe."

As a practical illustration of the great utility of the existing canal to the port of Baltimore for northern commerce, the statement of the agent of the New York and Baltimore Transportation Line is quite pertinent, since this company ran two lines of boats to New York, one via the canal and Delaware River rounding Cape May, and the other via Chesapeake Bay rounding Cape Charles. It was found that the time required by the canal route was only half that taken by the bay boats.* Another remarkable fact is stated to be the detention from ice which is actually found to give more trouble to the fleet using the lower bay route than to that using the canal. This opinion is based upon the use of the canal by that company for fifty years, and hence the agent of that line claims that "it is worth something."

The attitude of the far-sighted, patriotic and progressive citizens of Baltimore is further shown by the interest manifested in the project by the former President and Receiver of the Baltimore & Ohio R. R., Mr. John K. Cowen, who before investigation thought that the Sassafras route was the best, but after a careful personal investigation he went before the Congressional Committee and urged the enlargement of the Chesapeake and Delaware route, as being the most advantageous for the interests of the country served by his line, as well as for Baltimore. He distinctly stated that with this present canal enlarged and made free his company would ship its New England coal from the Port of Baltimore and in that event the railroad could haul as much in one car as now required two and a half. And, he added:

"I thought the Casey Board, in recommending the Chesapeake and Delaware Canal route, had overlooked the very largest item of coastwise commerce that would pass through the ship canal. I am prepared to say that directly from the Baltimore and Ohio Railroad at least two million tons of coal destined to New England ports, would pass through it, that this

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*See Ex. Doc. 102 53d Cong. 2d Sess. H. R., p. 105.

tonnage would probably increase until it more than doubled the two million figure, and further, that coal to the extent of a million tons, now going via rail to New York harbor, would probably go in vessels via the canal instead."

This was in January, 1901. Thus more than 5,000,000 tons of coal would be distributed at a saving of over a dollar a ton if the canal were enlarged as desired by the consumers and manufacturers of the country. This great economy of $5,000,000, on one item of commerce, would justify an expenditure of

Ericsson line steamer, passenger and freight. Daily trips, Baltimore-Philadelphia.

$100,000,000 if capitalized at 5 per cent. The existing canal is an insuperable barrier to vessels requiring more than ten feet of water, and commerce importunes Congress for its removal.

FACILITIES FOR CONSTRUCTION.

Although this canal is but $13\frac{5}{8}$ miles in length, only one-fourth of this distance involves any considerable amount of work, as the route occupies the bed of several creeks and it is only necessary to pump the mud from the bottom over the

dike which forms the tow-path and fill up the swampy reaches, thus converting them into arable lands or commercial frontages. The "deep-cut," which is a little over three miles long, and seventy-six feet deep at the summit, was excavated in 1826-9 by hand labor, and gave some trouble until the slopes had assumed a condition of equilibrium, but for the past 20 years or more there has been no difficulty in maintaining the full depth of the channel. During the past 25 months the average dredging done to remove the wash from the steamers was but 28 cubic yards per diem in this cut.

Common road swing bridge, Delaware City.

Borings made under the several surveys have revealed no rock in place and the existence of the waterway enables the work to be attacked at any point by hydraulic dredges and thus reduces greatly the cost of the enlargement, as well as the time for completion.

Neither is it necessary to suspend navigation.

The summit level, which is 16 feet above mean low water, is surmounted by two locks, one at Delaware City of 6 feet on the east, to overcome the tides, and another at St. Georges of 10 feet lift to reach the upper level, while the entire lift is

comprehended in a single lock at Chesapeake City on the western end, where a reservoir serves to save half of the water required for lockage. The deficiency in the supply is furnished by two large engines which lift the tidal water from Back Creek by means of a large bucket wheel.

The auxiliary works consist of the usual bridges, reservoirs, drains, wiers, siphons, locks, buildings, &c., which, with the

Swing bridge at Summit (Buck's)

excavations and enlargements, are estimated to cost about $5,000,000, exclusive of the franchises.

TRAFFIC.

On the present limited draught of ten feet the enormous tonnage of the two bays cannot use this route and is compelled to go outside, involving great loss of time, risk and expense. The official reports of the U. S. Engineers show that there are about 50,000,000 registered tons of commerce in the waters immediately tributary to the Chesapeake and Delaware Bays, and of this only about 700,000 freight tons can use the canal. If it were deepened to 20 feet even, then 75 per cent. of the

vessels could pass through, and many of them would doubtless soon do so if there were no obstructing tolls. In this case there would be an enormous traffic, while the railroads would

Three oyster sloops in St. George's Lock.

be relieved of the bulky freights at the nearest seaports and be enabled to utilize their rolling stock to much better advantage, not only because of the shorter haul but because of the higher class freights carried.

The precedent furnished by the Sault Canal since its several enlargements should suffice to show that the commerce grows faster than the Government can provide facilities and that absolutely no interests are injured thereby.

If the railroads and the people fully appreciated the benefits to be derived from a segregation of the bulky freights, wherever possible, from overland carriage, the conditions of traffic would be greatly improved for the good of all interests.

To effect this result, opposition to waterway legislation must be removed and a far more comprehensive system be inaugurated for the conduct of these works on a broad basis, by dividing the country into districts based upon the drainage systems, and appointing permanent officials, with sufficient authority to conduct the local improvements, but at the same time giving every possible latitude to all private and corporate efforts to make improvements at their own cost and risk, as has been done so successfully in the rail and common road systems of our country.

PRODUCTION OF BORAX IN 1905.

The production of borax, says Mr. Charles G. Yale of the United States Geological Survey in his report on the output of that mineral during 1905, is now almost entirely confined to the State of California, and to the counties of San Bernardino, Inyo, and Ventura in that State. Only small quantities are occasionally taken from the marshes of Nevada, where a little work is carried on during the summer months.

The total output of crude borax for the year 1905 was 46,334 short tons, valued at $1,019,154, as against 45,647 short tons, valued at $698,810 in 1904, an increase of 687 tons in quantity and of $320,334 in value. The average value of the crude borax product in 1905 did not actually increase in this ratio to the somewhat increased quantity, so that an explanation of the figures given is due those whose interests the statistics may serve.

In the process of manufacturing borax and boracic acid, it takes from 2 to 4 tons of crude borax to make 1 ton of pure anhydrous acid, depending on percentage of the ores handled. When the crude product, worth at the mines from $15 to $50 a ton, is refined, it is worth on the market, as a manufactured product, from $120 to $140 a ton. When mined and shipped none of the material is pure borax and about six-sevenths of the total is only 25 per cent. ore, the other seventh being more or less concentrated but not refined. The miners themselves agree that in calculating the quan-

tity and value of the product for statistical purposes the crude material only should be considered, as the costs of refining vary with the process.

The valuable element in the crude borax of California is anhydrous boric acid, of which the prepared borax of commerce contains 36.6 per cent., the other elements being soda and water added in the process of refining. The manufactured product is worth from $120 to $140 per ton, but the boric acid content and its fair commercial value at the place of production are evidently the only proper considerations for the statistical purposes of this service. The crude material as it comes from the ground varies in boric acid content, according to the nature of the deposits, from about 5 per cent. to about 35 per cent. Under the conditions the uniform plan of calculating the value of the crude material according to the percentage of boric acid contained has been accepted, and, with the advice of leading producers, it has been assumed that this product in 1905 was worth $120 a ton at the mine, making the crude material worth $1.20 for each unit, or per cent., of boric acid carried. This percentage is reliably known for each mine. Some of this boric acid is used as such in the industries, but the bulk of it goes into the manufacture of borax. Had the entire output been made into borax, the resulting refined product, at an average value of $130 a ton, would be worth $3,016,260.

The figures given for 1905 represent the total tonnage of crude material, regardless of its percentage of boric acid, and the value based on the boric acid content of this crude material.

Mr. Yale's report is published as an advance chapter from the annual volume "Mineral Resources of the United States, 1905," and is intended for general distribution.

PRODUCTION OF CHROMIC IRON ORE IN 1905.

California was the only State producing chromite during 1905. The quantity produced was 25 long tons, valued at $375, as compared with 123 long tons, valued at $1,845, in 1904, with 150 long tons, valued at $2,250, in 1903, with 315 long tons, valued at $4,567, in 1902, and with 368 long tons, valued at $5,790, in 1901.

PRODUCTION OF PLATINUM IN 1905.

The production of platinum from domestic ores in 1905 was 318 ounces, valued at $5,320, as compared with 200 ounces, valued at $4,160 in 1904; with 110 ounces, valued at $2,080 in 1903; with 94 ounces, valued at $1,814 in 1902; with 1408 ounces, valued at $27,526 in 1901; and with 400 ounces, valued at $2,500 in 1900. In December, 1904, the price of ingot platinum at New York advanced from $18.50 to $19.50 an ounce; in April, 1905, it was $20.50; in February, 1906, it advanced to $25, and in September, 1906, it was $34 an ounce.

Mining and Metalurgical Section.

(Stated Meeting, held Thursday, March 8th, 1906.)

The Manufacture of Rolled Sterling-Silver.

By Erwin S. Sperry,

Editor of "The Brass World," Bridgeport, Conn.

Within the past twenty-five years the manufacture of sterling-silver has undergone a remarkable change. It is not difficult to remember when an article of this metal was considered a household luxury and only the wealthy could afford it. Well-to-do people possessed a small quantity, handed down as an heirloom, perhaps; and people in moderate circumstances had to be content with pewter or tin-ware for common use, with a meagre assortment of plated-ware for special occasions. On particular occasions, the family heirlooms of sterling-silver, which usually consisted of one or two table-spoons and half a dozen tea-spoons, were carefully cleaned and polished and arranged on the table so that they would make the best showing. After such service they were returned to their former hiding place to prevent theft.

This unique condition has now changed. Instead of being confined to the wealthy or well-to-do people, sterling-silver is found in even large quantities in families who in former times would have been considered extravagant had they possessed the stock which they now have. The reason for this apparent paradox is not the reduction in the price of silver, but in the cost of manufacture.

The method pursued by the old-time silversmith for making spoons or forks was to hammer them out by hand from a rod. By means of files and saws the article was made to assume its shape. No doubt, the reader has seen examples of this early silversmithing and has noticed the marks of the hammer upon

them. Costly operation that it is, our British friends still continue to use it for the manufacture of their wares. Even in our own progressive country, a few manufacturers continue to manufacture goods in this manner, but only upon work which will warrant it. Such work is always upon special designs which would not warrant the necessary expense for dies.

The change which has been responsible for the cheapening of sterling-silver wares is the use of *rolled sheet metal* for its manufacture. Articles which heretofore were made from rods are now made by stamping from sheet metal and with the employment of modern machinery instead of hand labor. This sheet metal is the foundation of the manufacture of modern sterling-silver ware, and it is my intention to describe the various operations employed for its production.

Trade conditions at the present time are such that it hardly pays the manufacturer of sterling-silver wares to make his own sheet metal, and nearly all of the establishments of this nature in the United States now purchase the sheet from mills that make a specialty of rolling. The condition is analogous to that which exists in the brass trade. It has been found that the manufacture of the sheet metal and the production of finished wares are quite distinct, so that the present policy of the sterling-silver manufacturer is to purchase his sheet metal and not manufacture it. The fact that a large and extensive equipment is required for the manufacture of rolled sheet metal is usually a sufficient reason why the majority of manufacturers do not care to make it.

Sterling-silver, as now made in the United States, consists of 925 parts of pure (fine) silver and 75 parts of copper. Pure silver itself is too soft for use in articles which are to hold their shape. At the beginning of the so-called "cheap silver era," or when sterling-silver ware began to be manufactured by modern methods, a manufacturer occasionally was found who cheated the purchaser by making ware with less than 925 parts of silver in it. To-day, however, no one would dare to do this. Laws in several States regulate the quantity of silver which an article stamped *sterling-silver* must contain. These laws do not stipulate the alloy nor the exact proportions, but state that not less than 925 parts of fine silver shall be present in 1000 parts of metal.

The silver which is used in the manufacture of sterling-silver sheet is known as *fine silver bars.* It is also called *bullion,* but as bullion may mean impure silver as well as the pure material, it is now customary to designate the metal that is employed for sheet rolling by the former name. These fine silver bars are purchased from the various smelting works that smelt silver ores. The electrolytic copper industry also furnishes a supply. These bars are received from the express company (all bullion is transported by express) in a loose condition, as

Fig. 1. 500 Oz. Bars of Fire Silver Valued at Over $10,000.

it has been found easier to watch or verify them if sent in this manner. When the bars are received from the express company they are loaded upon a mill truck as shown in Fig. 1 and immediately counted. Any loss, therefore, is detected at once.

The fine silver bars which are shown in Fig. 1 are known as "500 oz. bars," on account of their weight. Such bars have been found to be the most convenient. Bars may also be obtained weighing 1000 and 200 ounces. The value of silver needs no explanation and every precaution is taken to prevent theft. The bars which are shown in Fig. 1 have a value of over $10,000.

The bars are now immediately weighed upon bullion balances, as shown in Fig. 2, in order to ascertain whether the correct amount has been received. If any bar has been tampered with the loss is at once apparent. The balances are capable of weighing as small an amount as 0.01 oz. Troy, which is sufficiently accurate for the ordinary weighing of silver.

The storing of large quantities of silver, both in the form of

Fig. 2. Weighing the Fine Silver Bars When Received.

bullion or in process of manufacture, is a problem which has had to be solved, as it is not unusual for silver to the value of several hundred thousand dollars to be partially completed. This problem has been solved by the use of a vault. The vault which is commonly used for this purpose closely resembles a bank vault. It is both fire and burglar proof. The inside brick walls are filled with fine copper wires so that the rupture of any one of them, that would take place should an attempt

be made to enter the vault, is at once made known at some central station.

The "fine silver bars" which are used for the manufacture of sterling-silver and which are shown in Fig. 1 are always stamped on the bottom with the weight, number and fineness. The mark used to designate the fineness is always the same and no attempt is made to raise the fineness of the silver beyond 999 parts in a thousand. It has been found not only quite expensive but unnecessary to raise the fineness beyond the 999 point, and silver of this purity answers every requirement. It is such silver, 999 fine, that is used in the manufacture of sterling-silver sheet.

In Fig. 1 are shown 500 oz. bars. Bars weighing 1000 oz. and 200 oz. may also be obtained, but it has been found that the 500 oz. bars are the most convenient for use. The 1000 oz. bars are too large for crucible melting. The 200 oz. bars are satisfactory, but more handling is required in using them, and, therefore, they are not extensively employed.

The fine silver bars shown in Fig. 1 are frequently known as *Commercial Silver Bars* to distinguish them from *Assay Bars* made by the United States Government. *Assay Bars,* however, are no better than *Commercial Bars* and experience has demonstrated that no better results can be obtained by their use. Our Government does not sell silver, and in order to obtain Assay Bars it is necessary to place a certain amount of silver in the Assay Office in New York City for refining. The quantity of silver, 999 fine, which is obtained from it is returned to the depositor and a refining charge is made. The Government stamp upon them, to many persons, would seem to indicate that the silver is better than Commercial Bars, but such is not the case. The Government makes no attempt to raise the fineness above 999.

In the manufacture of sterling-silver which, as previously mentioned, consists of 925 parts of fine silver and 75 parts of copper, it is customary to use shot copper. This variety of copper is made by melting the purest copper that is obtainable (Lake copper) in a graphite crucible and then pouring it at a considerable height into cold water. The copper cools in the form of shot. In Fig. 3 is shown a batch of shot copper ready for use. The fine state of division of this variety of copper

renders it a simple matter to make up any given weight. The copper which is used in making sterling-silver is called the "alloy."

The fine silver and the shot copper are now weighed upon accurate bullion balances in the proportions which are necessary to produce sterling-silver. In the majority of sterling-silver mills it is customary to use a No. 40 graphite crucible for melting the silver and this holds about 1200 oz. As a large amount of scrap constantly accumulates, the amount of fine silver and shot copper that are weighed are sufficient to fill

Fig. 3. Shot Copper Used in Making Sterling-Silver.

only half the crucible. The remainder is filled with scrap. A small amount of copper oxidizes in melting so that while the original fineness may have been 925, after the sterling has been cast, the fineness will frequently be found to reach 926 or even 927. Allowance is made for this oxidation. One or two thousandths, however, are usually considered as close at it is possible to make sterling-silver when considerable scrap is used.

The copper is placed in the bottom of the crucible and the silver on top. No scrap is put in at this period but is with-

held until the copper has melted. The silver having a lower melting point than copper, melts first. When the silver begins to melt, charcoal is added to the crucible so that it completely covers the metal. This is imperative, as without it the copper would oxidize.

The crucibles which are used are of the ordinary variety employed for brass melting. In some establishments a crucible known as a "Tube-Nosed Pot" is used. This is a crucible with a tube down the side which renders it self-skimming. Beyond the advantage of skimming they have no value and silver

Fig. 4. Oil Furnaces Used for Melting Sterling-Silver.

manufacturers seem to differ about their value in melting. Personally, I have found them quite advantageous, but many silver makers have not found them so.

For melting the silver, crude oil has been found to be very satisfactory. Its freedom from sulphur and the fact that it produces no ashes have greatly appealed to the sterling-silver maker and at the present time nearly every one in the United Stats uses it for this purpose. It is cheaper than gas, although not as convenient. The cost of a good quantity of gas has prevented its use in the manufacture of sterling-silver. The fact

that coal or coke leaves ashes to be ground has brought about the use of oil for melting. The value of silver is so great that every particle must be saved. The constant accumulation of ashes, therefore, which invariably contain more or less silver, has always been a difficult problem, but the use of oil has solved it.

The furnaces used for melting sterling-silver are a shell of cast iron lined with fire brick. A burner enters at the bottom and strikes at a tangent so that the flame does not directly impinge upon the crucible. These furnaces are shown in Fig. 4. When everything is in good working condition, the melting operation usually takes about forty minutes. Air is used for spraying the oil and the noise which this blast produces is one of the objections to the use of oil. The melters, however, soon become used to it.

As the silver melts before the copper and settles to the bottom of the crucible, great care is required in ascertaining whether all the copper has melted. A rod of graphite crucible mixture is used for stirring the mixture, and this is frequently done by the melter to make sure that all the copper has melted and alloyed with the silver. Charcoal is added to the crucible when needed and care is taken to see that the surface is not exposed at any time. When the copper has melted and the mixture has reached the required temperature, it is ready for pouring. The determination of this "pouring heat" is an operation which requires skill, and unless the melter understands his business good sterling-silver cannot be made. Too low a temperature will result in a cast plate full of "cold-shots," while one poured when the heat is too high will result in blow-holes and the cracking of the metal in rolling. Pyrometers have not been extensively used for the determination of the pouring temperature, but they will undoubtedly be largely employed as soon as one is found which is capable of giving accurate and uniform results in inexperienced hands.

When the sterling-silver is ready for pouring, the crucible is lifted from the furnace by two men by means of basket tongs and is immediately poured. In Fig. 5 the operation of pouring a sterling-silver plate is shown. The crucible which is shown is of the "tube-nosed" variety.

The mold that is used is of cast iron and in halves so that the

plate may readily be removed. It is held together by means of an iron band and wedge. The mold is coated with whale oil before using. A good sized stream is used in pouring so that the mold is rapidly filled. No attempt is made, as it is in the brass industry, to fill the "shrink" at the top of the mold. Sterling-silver shrinks very little in cooling and only a slight depression is found on the top of the plate.

This pouring operation is supposed to be one of the

Fig. 5. Pouring a Sterling-Silver Bar or Slab to be Used for Rolling.

"secrets" in the manufacture of sterling-silver; but, as a matter of fact, the only "secret," if it can be called such, is in the determination of the pouring temperature. At the present time this point is determined by the eye, but it is quite probable that the advent of a suitable pyrometer will reduce the operation to a business basis.

One of the former "secrets" in the manufacture of sterling-silver, but now common property, is the use of cadmium for imparting soundness and malleability to the metal. It is customary to add 5 parts of metallic cadmium to 1000 parts of

sterling mixture. This amount is deducted from the copper so that the actual mixture becomes:

Fine Silver	925 parts
Shot Copper	70 parts
Metallic Cadmium	5 parts

The cadmium is added after the copper and silver have melted. It is pushed down under the metal with tongs so that it will not rise to the surface and burn. The function of cadmium is to remove the oxygen from the silver and in this respect it has been found so advantageous that it has replaced every other deoxidant and practically every manufacturer of

Fig. 6. The Bar or Slab of Sterling-Silver as Cast.

sterling-silver in the United States now uses it for this purpose.

The cooling of a large mass of silver in the air is a slow operation, so it is customary to plunge the plates after they have "set" and are removed from the mold, into cold water. This sudden chilling of the plate does not seem to have any bad influence on the rolling qualities of the silver, and by thus quickly cooling it work may be commenced upon it at once.

It is customary in the sterling-silver industry to cast one size of plate and then widen it if a wide sheet is required. In Fig. 6 a cast plate of sterling-silver is shown. This plate is 1¼ inches in thickness, 10 inches wide and 12 inches long. The

plate shown in Fig. 6 is just as it came from the mold. After the fins have been removed the top end is cut off on large alligator shears. The object of cutting this end is to remove the imperfect portion of the metal. The top is not so dense and sound as other portions, and if the plate is rolled without cutting off this end, imperfect sheet would be produced. It is quite difficult to detect such imperfect metal after the sheet has been rolled, so that the practice of cutting off the end before rolling has been adopted. This is called "cutting-off the gate." Usually one cut is all that is required, but now and then when the center of the plate is quite crystalline another cut has to be taken. The center of the plate is usually crystalline near the top and the object of the cutting of the end is to remove it. Dross, too, frequently rises and this is likewise removed when the gate is cut off.

The plate is now ready for "overhauling." This operation has long been used for removing the surface of a plate before rolling. No one has yet devised a process for casting perfect metal, and although sterling-silver runs freely and without oxide, the surface of the plate is never clean. Charcoal, slag, or pieces of crucible are always found on the surface of the cast plate.

The overhauling machine consists of a bed similar to a planer bed upon which the plate is clamped. An overhanging arm carries a tool which is made to scrape the surface of the plate by means of a crank and cam. The tool may be made to take a heavy or light cut by means of a treadle manipulated by the operator. The fact that any particular portion of the plate may be scraped more than another is wherein the overhauling machine differs from a planer. A planer removes an equal amount of metal from one end of the plate to the other, while the overhauling machine enables the operator to remove the metal from any particular portion which may require it. It often happens that certain portions of the plate require no scraping while others have to be scraped deeply in order to thoroughly remove an imperfection.

After the plate has been overhauled, it is ready for the first rolling operation called "breaking-down." The rolls which are used for this purpose are of chilled iron and ground with a smooth surface. As the object of this breaking-down pro-

cess is to reduce the metal as rapidly as possible, the rolls and housings are made sufficiently strong to bear the strain which is put upon them. This "breaking-down" process does not require as skilled labor as finishing the metal and the wages are correspondingly less.

All sterling-silver is rolled cold and the plate is passed through the rolls with as heavy "pinches" as can be given it. A "catcher" stands behind the rolls and passes the plate back to the roller after it issues from them. In Fig. 7 is shown the

Fig. 7. "Breaking-Down" the Sterling Silver. First Operation in Rolling.

breaking-down operation. The plate is rolled to a thickness of $\frac{3}{8}$ of an inch in this "breaking-down" operation. If a wide sheet is required, the plate is passed through the rolls diagonally so that the metal is widened and lengthened at the same time. This widening operation is called "cross-rolling."

The rolls shown in Fig. 7 are 18 inches in diameter and 30 inches long. The adjustment is by means of a crank at the left hand side of the rolls. Both ends of the rolls are raised and lowered at the same time. This adjusting mechanism

answers very well for "breaking-down" rolls, but for finishing rolls, an overhead adjustment by means of screws and "spanners" are the best.

After the plate has been "broken-down" to $\frac{3}{4}$-inch the metal has reached the limit of rolling and any further reduction would tend to injure or fatigue it. In order to overcome the hardness which the rolling has imparted to the plate and to

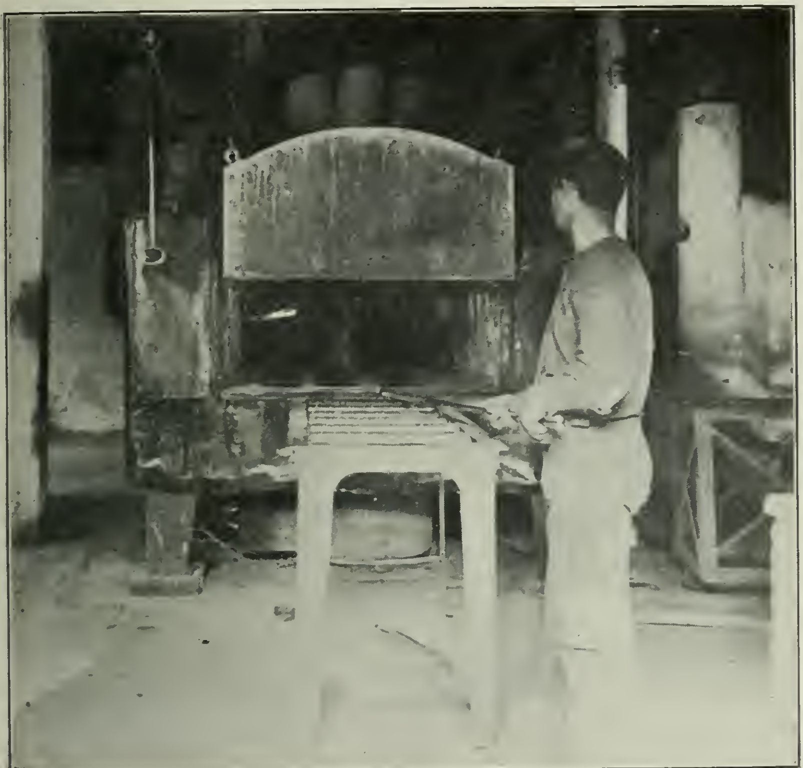

Fig. 8. Annealing Muffle.

soften it so that further rolling may be done, the plate is annealed.

The annealing is carried out in a muffle (shown in Fig. 8) lined with fire brick and heated with oil. As soon as redness has been reached the plate or sheet, which it now is, is plunged into a sulphuric acid pickle. This pickle is composed of sulphuric acid (oil of vitriol)

and water in the proportion of about one part of acid to sixteen of water. The sheet is plunged while it is red hot into the hot pickle and in this manner the black oxide of copper which forms on the surface during the annealing is removed in a few seconds. The sheet is then rinsed in water and dried. As it has been found that silver is injured by allowing it to remain too long while red hot, great care is required in annealing to avoid excessive heating. The simple heating to a red heat is all that is required. The pickle which is used dissolves some of the silver as well as the oxide of copper which is on the surface. At frequent intervals salt is added to the pickle, and the precipitated chloride of silver is allowed to settle and is then removed.

The pickled sheet now presents a uniformly white surface and without lustre. Any imperfections which have developed during the "breaking-down" are now plainly revealed and are removed by a second overhauling and an operation called "chipping." This "chipping" operation consists in removing small particles of charcoal or similar imperfections which have become bedded in the surface. A hammer and chisel are used for the purpose, but care must be taken so that the hole which is produced will not fold over on itself in the next rolling. By making the hole dish shaped the edges will not fold over.

The sheet of sterling-silver after it has been annealed and pickled is warped so that it will not lie flat upon the table of the overhauling machine. The sheet is therefore straightened upon a machine known as a "three-roll straightener." This appliance consists of three rolls arranged in pyramid form, that is, with two rolls at the bottom and one at the top. In order to use them it is first necessary to curve the sheet and then adjust the top roll so that the sheet is flattened. This operation is frequently explained by saying that the sheet is "first made sick before it is made well."

After the sheet has again been overhauled, it is ready for the next rolling operation, called "running-down." The rolls which are used for this purpose are the counterpart of the "breaking-down" rolls but are kept in a better condition. The "running-down" process consists in rolling the sheet to No. 10 B. & S. gauge. The sheet is then elongated so that it requires coiling before it can again be annealed. The sheet is usually

10 or 12 feet long. Another annealing is then given it followed by pickling, and the sheet is then carefully inspected for further imperfections. If any are found they are removed by means of a hammer or chisel. Deep chipping must now be avoided, however, and only superficial imperfections can be advantageously treated. In this manner the elimination of the chipping marks is assured, but deep holes will not be removed by the subsequent rolling.

The sheet is now ready for the final rolling process called

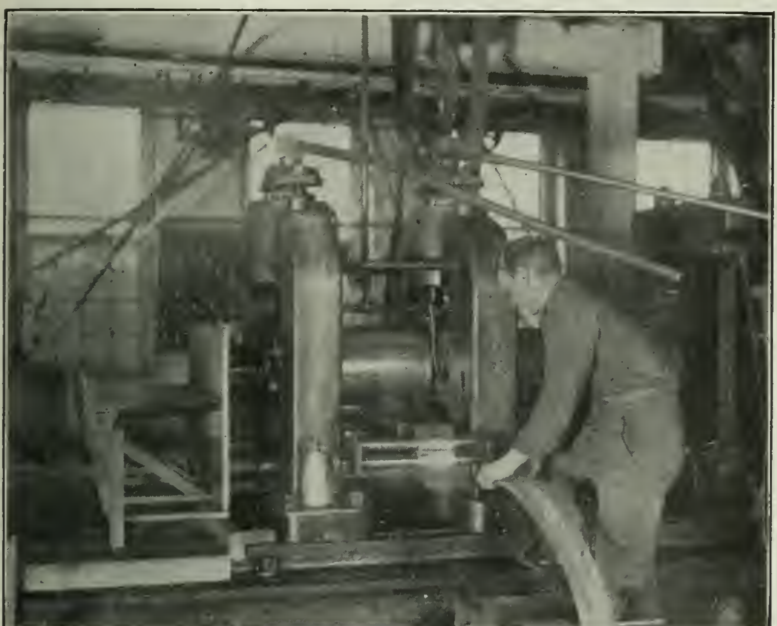

Fig. 9. The Finishing Rolls.

"finishing." The rolls that are used for this purpose are chilled iron, but the surfaces are kept in a more highly polished condition than either the "breaking-down" or "running-down" rolls. The adjustment is by means of overhead screws operated by long spanners so that one side of the roll may be raised or lowered independently of the other end. Any tendency towards crookedness in the sheet as it issues from the rolls may, therefore, be corrected. In Fig. 9 is shown a pair of finishing rolls in operation.

It is in the finishing of sheet metal that the skill in rolling is displayed. All spinning or drawing operations, in which sheet metal is used, demand that an accurate gauge shall be furnished. For this reason, the finishing roller must understand his business or great inaccuracy will follow. A device called a "bridle" is used for straining the sheet as it passes through the rolls. If this is not done the sheet cannot be kept straight. In wide sheets a "wedge" is used; this may be seen between the rolls and bridle in Fig. 9. The wedge and bridle are frequently used together, but the bridle can only be used for thin sheet. Neither can the wedge be used for thin sheet as the strain cannot be accurately adjusted and the sheet will tear. The bridle, however, enables the roller to adjust the tension so that the thinnest sheet may be rolled.

Back of the rolls is a wooden cylinder attached to a revolving shaft. The sheet as it comes from the rolls is attached to this "block" and a coil is thus produced. A band of copper wire prevents it from springing apart. As practically all sterling-silver sheet is sold in the annealed form, the coil is now returned to the annealing muffle and again annealed and pickled. More care is now exercised in the handling to avoid scratches or dents and when the coil comes from the rinse water it is dried in maple sawdust so that a uniform surface is produced. An appliance called a "drying-out machine" is employed for this purpose. It consists of a long box in which sawdust is placed. On one end is a coiling drum operated by a belt. The sheet is started through the sawdust and attached to the drum which draws it rapidly through. Revolving brushes remove the surplus sawdust from the sheet after it issues from the box. Pine sawdust cannot be used for this purpose, as the pitch which it contains leaves streaks upon the surface of the silver. In order to obtain the best results, the sawdust is used warm and a steam coil underneath the box heats it to the required temperature.

As the various articles which are made from sterling-silver require varying widths, it is necessary to slit the sheet to the required dimensions. A rotary slitting machine is used for this purpose and both sides of the sheet are trimmed at once. If great accuracy is not required in the width of a sheet, it is preferable to slit the sheet before it goes to the finishing rolls.

Fig. 10. Inspecting the Sheet.

The object of this procedure is to avoid scratches or dents, which invariably are produced when a soft metal like sterling-silver is handled. The surface after annealing and pickling is dead white and is particularly susceptible to abrasion. In Fig. 11 the finished sheet may be seen and the dead white surface is quite apparent. The need for careful treatment is, therefore, far greater than in brass or german-silver.

The final operation is the inspection of the sheet, and as no requirement is more severe upon a metal than spinning or

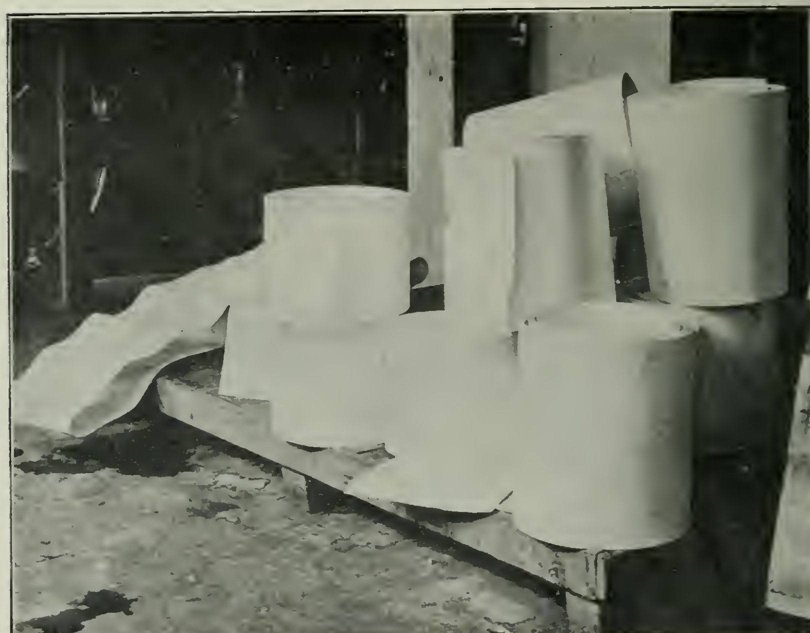

Fig. 11. The Finished Sterling-Silver Sheet Ready for Shipment.

drawing, nothing but perfect sheet can be allowed to go to the customer. In Fig. 10 the inspecting operation is seen. The sheet is unrolled upon a bench and every part of the surface is searched for imperfections. The specks of dirt often deceive the inspector, but a little scraping with a knife will reveal their true nature. If it is found that the imperfections are such that the sheet is injured, the whole is cut up and remelted. It usually happens, however, that sheet is sold in short lengths, so that by judicious slitting or trimming the imperfections may

be removed. The sheet is now rolled into coils as shown in Fig. 11 and is ready for shipment.

A word about the grinding of the rolls may be of interest. This operation is one of the most peculiar in the rolling mill industry. One would naturally think that an emery wheel could be rigged so the rolls could be ground in place, or if not, it is a simple matter to remove them and grind them in a lathe. While both of these methods are used for grinding the rolls before they are inserted in the housings, they do not answer for the production of the required surface. The method which is now pursued for grinding a pair of chilled rolls that are used for cold rolling silver, brass, or copper is by means of a hard wood stick and emery. The stick is covered with oil and emery, inserted between the rolls and moved gradually from end to end. The object of this apparently primitive method is not to produce a polished surface upon the rolls as one might naturally think, but to impart the necessary "crown" to the rolls. Although chilled rolls seem proof against any bending, it is an actual fact that they do spring when a piece of metal is rolled. If, therefore, a pair of rolls were used with a "flat" surface, i. e., straight from end to end, the "spring" would cause the rolls to become concave and a sheet would thus be produced which would be thicker in the middle than on the edges. In order to guard against this unevenness of gauge, the rolls are ground so as to allow for the amount which they "spring."

As the thickness, width, and hardness of the sheet which is to be rolled, cause the rolls to "spring" to a varying amount, it is obvious that a uniform "crown" cannot be given to them. It is in the grinding of the rolls that the skill in rolling is displayed and a roller who can grind a pair so that a sheet of metal will have a "lay" to it and with uniform gauge, is worthy of the name of an "expert roller." The most difficulty arises in rolling wide sheets and only those who are highly skilled in the art of rolling can roll sheet of this character.

MEASUREMENT OF NATURAL GAS.

Statistics of the quantity of natural gas consumed in the United States will be taken next year by the United States Geological Survey. Up to the present time, only the value of the gas has been ascertained. The adoption of this method will make it inconvenient, if not impossible, to refer back for purposes of comparison to the figures of previous years, but it will result in more direct knowledge of the capacity of gas areas to maintain a commercial supply of gas for a certain number of years.

An effort will be made to collect and publish statistics showing the total acreage held by natural gas companies and the acreage operated by them, with the total quantity of gas consumed in the different States. Owing to the fact that gas wells from different fields are connected to the main pipe lines, and that gas is only measured where consumed, it is now almost impossible to procure exact figures as to the quantity of gas produced from any particular district.

When natural gas was first brought into use an idea prevailed that the supply was inexhaustible. It was sold at low rates and usually without measurement. This method encouraged waste in the consumption of natural gas and was shortly abandoned by the larger companies. They introduced meters and sold their gas at a rate per thousand feet by measurement. There were, however, so many smaller companies that did not measure the gas consumed that it was impossible to secure reliable figures of the production and consumption of natural gas in thousands of cubic feet. For this reason the statistics of this valuable product have been collected in terms of value.

In taking only the value of the product, however, as a basis for statistical record an incorrect idea is given of the actual production of the gas fields, for with the diminution in volume the price has been increased, and in recent years in some cases an increased value is shown where there has been a decided falling off in the production of gas. Experience has demonstrated that there is a limit to the production of all fields, and those who handle the gas have learned that the unnecessary waste of this valuable resource must be prevented. To-day nearly all consumption is sold by measurement. It is believed that the time has come when it is possible to procure statistics of the quantity of gas consumed. Announcement of the Survey's intention to make the endeavor next year is contained in the recently published report by Mr. .W T. Griswold entitled "The Production of Natural Gas in 1905."

PRODUCTION OF LEAD IN 1905.

The production of lead in 1905 was 302,000 short tons, as against 307,000 short tons in 1904 and 282,000 short tons in 1903. The value of the production in 1905 was $28,690,000, as compared with $26,402,000 in 1904, and with $23,520,000 in 1903.

(Stated meeting held Thursday, December 20, 1906.)

The Efficiency of Furnaces.

By Dr. Joseph W. Richards.

"Efficiency" may be considered in many various aspects. The most general meaning is the quality of accomplishing the desired purpose at the minimum cost. This is a very complex quantity, and must be discussed from the most general and varied standpoints. Again, one furnace accomplishes a certain work with one-half of the fuel which another furnace uses, and we can therefore speak of the first furnace being *relatively* twice as efficient as the second, as far as fuel consumption is concerned. But, besides relative efficiencies, there is such a thing as *absolute efficiency*, when speaking of thermal efficiency;—that is, the ratio of the net thermal effect produced to the heating power of the fuel.

We will take up the subject first as regards *Thermal Efficiency*, both absolute and relative, and conclude with a discussion of *Efficiency* in its most general meaning, as relates to minimum cost.

THERMAL EFFICIENCY.

A view of efficiency which in many cases leads to the most revolutionary ideas in practice, is to compare the actual net heating effect produced with the total heat used to produce it. To make a comparison, one steam boiler may be 50 per cent. more efficient than another, in regard to coal used per ton of water vaporized, and a third 20 per cent. still more efficient; yet when we learn that these three boilers only return 30, 45 and 54 per cent. of the heating power of the coal, as heat in dry steam, we realize that there is still considerable room for improvement. In short, comparisons of general efficiency are only relative, while the calculation of net thermal efficiency

gives absolute data which are of the highest scientific interest and practical importance.

We must distinguish rather sharply, however, between two classes of operations, which do not allow of the application of the same standards of efficiency. These are (1) those requiring a definite amount of thermal effect to be produced, independent of the time, and (2) those which require the application of a certain temperature for a given time. We will explain more at length.

In operations of class (1) we wish to bring a substance into a given condition by the application of heat, and the *time* factor is sub-ordinate or negligible, the principal or controlling factor being the net amount of heat *absorbed* in the operation. In operations of class (2), the material usually absorbs some heat in being brought up to working temperature (and this part of the operation is identical with the whole of an operation of class 1) but here the material must be kept at this temperature for a shorter or longer period, simply for the physical changes which the temperature produces, and during this period no more heat is absorbed by it.

Thermal Efficiency (Class 1.)

The problem is, having a given substance or mixture of substances in a given physical or chemical condition, to apply heat so as to change it to a different physical or chemical condition, the said change absorbing a definite amount of heat energy in calories. Under such conditions, determine the thermal efficiency of the furnace. Here we must distinguish three cases: (A) when the desired change is merely one of temperature; (B) when the change is a mixed physical and chemical effect; (C) when the change is merely a chemical transposition.

(A) These form the simplest cases for determining thermal efficiency. Examples are as follows: The melting of metals or other substances for the purpose of casting them, the heating of metals to given temperatures for the purpose of working them, such as rolling, forging, etc.,—in short, all operations in which a substance is put into a furnace simply for the purpose of making it hot, or melting it, and then taken away from the furnace to be worked or used in the hot condition. In all these

cases, the thermal efficiency is simply the heat imparted to the body, divided by the total heat available in the furnace.

Illustration 1: An iron-foundry cupola melts 1000 kilograms of pig-iron by the use of 140 kilograms of coke, having a calorific power of 7000 Calories, and yields 980 kilograms of melted iron, ready for casting, containing 275 Calories per kilogram, there being oxidized 15 kilograms of iron and 5 of silicon. What is the thermal efficiency of the cupola?

Solution: The net useful effect is $980 \times 275 = 269,500$ Calories, which has been obtained from burning 140 kg. of coke, with a possible calorific power of 980,000 Calories, and the combustion of 15 kg. of iron and 5 kg. of silicon. The last two items afford

15 kg. Fe to FeO	$= 15 \times 1173 = 17,595$	Calories.
5 kg. Si to SiO^2	$= 5 \times 7000 = 35,000$	"
	52,595	"

which is in fact increased further by the heat of combination of 19 kg. of FeO formed with the 11 kg. of SiO^2, to form slag, amounting to

11×148	= 1,630	Calories
Total heat of oxidation	= 54,225	"
Calorific power of the coke..	= 980,000	"
Total heat available	=1,034,225	"

$$\text{Thermal efficiency} = \frac{269.500}{1,034,225} = 0.260 = 26.0 \text{ per cent.}$$

Illustration 2: 100 pounds of pure Swedish bar iron and 50 pounds of "washed" pig metal are put into a steel melting crucible and melted down in 2 hours, using 200 pounds of coke, to melted steel containing 315 Calories per unit of steel (pound Calories per pound). Assuming the calorific power of the coke 7000 Calories, what is the thermal efficiency?

Solution: Heat in steel $150 \times 315 =$	47,250 lb.	Calories
Calorific power of the coke $200 \times 7000 =$	1,400,000 "	"

$$\text{Thermal efficiency} = \frac{47,250}{1,400,000} = 0.0337 = 3.37 \text{ per cent.}$$

Illustration 3: 1000 kilograms of pure Swedish bar iron and 500 kilograms of "washed" pig metal are put into the crucible of an electric melting furnace of the induction type, and are

melted down in one hour to melted steel containing 315 Calories per kilogram, by the expenditure of 1,000 kilowatts of current. What is the thermal efficiency?

SOLUTION: Heat in melted steel	1500×315	$= 472,500$	Calories.
Heat energy of 1 kilowatt second		$= 0.2389$	"
" " " " hour	$= 0.2389 \times 3600$	$= 860$	"
" " " 1000 " hours		$= 860,000$	"

Thermal efficiency $= \frac{472,500}{860,000} = 0.55 = 55$ per cent.

Such calculations as the above require a knowledge of the calorific power of the fuel used, data for calculating other sources of heat, and the net heat in hot or melted metals,—data such as are given in some of the larger compilations of physico-chemical data, such as Landoldt-Bornstein-Meyerhoff's tables, or the author's "Metallurgical Calculations."

Illustration 4: A regenerative gas furnace heats ten tons of soft steel ingots to 1000° C., using 900 cubic meters of natural gas of the following composition:

Hydrogen, H^2	22.50	per cent.
Methane, CH^4	60.27	" "
Ethylene, C^2H^4	6.80	" "
Carbon di-oxide, $CO.^2$	2.28	" "
Oxygen, O^2	0.38	" "
Nitrogen N^2	7.32	" "

What is the thermal efficiency of the furnace?

Solution: Heat in the hot ingots at 1000° is 166 Calories per kilogram, according to Pionchon's (re-calculated) tests; therefore, to 10,000 kilograms of ingots there are furnished

$$10,000 \times 166 = 1,660,000 \text{ Calories.}$$

Calorific power of the gas used per cubic meter:

Hydrogen	$0.2250 \times 2,613 =$	588	Calories
Methane	$0.6027 \times 8,598 =$	5182	"
Ethylene	$0.0680 \times 14,480 =$	985	"
Total		6755	"
per 900 cubic meters		6,079,500	"

Thermal efficiency $= \frac{1,660,000}{6,079,500} = 0.273 = 27.3$ per cent.

Examples could be multiplied almost indefinitely, from the metallurgical and metal-working industries, illustrating the applications of the above principles. They will be found es-

pecially valuable as indicating to the furnace designer and user the considerable room for improvement in thermal efficiency almost universally prevalent.

(B) When a considerable chemical change takes place in the mixture being heated, in order to get a hot product for casting or other hot-working, the heat absorbed or evolved in the chemical reactions must be also counted in. Such cases occur when melted metals are produced from the reaction of metallic ingredients. For example, pure (washed) pig-iron may be put into a crucible with enough pure magnetic iron oxide to burn out its carbon and produce steel. The heat in the resulting steel plus the heat absorbed in the chemical reaction is here the total useful calorific effect, and is to be compared with the calorific power of the fuel consumed.

Illustration 5: A charge put into a hot crucible consists of 100 pounds of "washed" pig-iron, containing 3.5 per cent. of carbon, and 13 pounds of pure magnetite concentrates, Fe^3O^4. Assuming the oxygen of the magnetite to form CO with part of the carbon of the pig-iron; that the steel resulting contains 315 lb. Calories per pound, and that 200 pounds of coke having a calorific power of 7,000 Calories is used, what is the thermal efficiency of the operation?

Solution: Oxygen in 13 pounds of Fe^3O^4

$$13 \times (64 \div 232) = 3.59 \text{ pounds.}$$

Carbon consumed $3.59 \times (12 \div 16) = 2.69$ "

Carbon remaining $3.50 - 2.69 = 0.81$ "

Weight of steel:

$$96.5 + 0.81 + (13 - 3.59) = 106.72 \text{ pounds.}$$

Heat in melted steel:

$$106.72 \times 315 = 33{,}617 \text{ Calories}$$

Heat absorbed in chemical reactions:

De-oxidation of iron $9.41 \times 1612 = 15{,}169$ Calories (absorbed)

Oxidation of carbon $2{,}69 \times 2430 = 6{,}537$ " (evolved)

Net $= 8{,}632$ " (absorbed)

Total heat absorbed $= 42{,}249$ "

Heating power of coke $200 \times 7{,}000 = 1{,}400{,}000$ Calories.

$$\text{Thermal efficiency} = \frac{42{,}249}{1{,}400{,}000} = 0.030 = 3.0 \text{ per cent.}$$

Illustration 6: Fifty metric tons (50,000 kg.) of pig-iron containing 3.5 per cent. of carbon, 2 per cent. silicon, and 1 per

cent. manganese is run into an open-hearth furnace, at 1250° C. As its temperature is being raised, red hematite ore is put in to oxidize out its impurities, a corresponding amount of iron being reduced. Heat in the pig-iron 275 Calories, in the finished bath (0.10 per cent. carbon), 350 Calories, per kg. During the heating 6,000 kilos of coal (calorific power 8500 Calories) are used in the producers. What is the net thermal efficiency of the whole plant (producers and furnace considered together)?

Solution: Oxygen needed from added ore:

Carbon 1,700 kg. × (16 ÷ 12)	= 2,267	kg.
Silicon 1,000 kg. × (32 ÷ 28)	= 1,143	"
Manganese 500 kg. × (16 ÷ 55)	= 145	"
Total	= 3,555	"
Ore required = 3.555 × (160 ÷ 48)	= 11,850	kg.
Fe in ore = 11,850 — 3,555	= 8,295	"

Final weight of bath:

50,000 — (1,700 + 1,000 + 500) + 8,295 "
= 55,095 "

Heat in original pig iron	= 50,000 × 275 = 13,750,000	Cal.
Heat in final bath	= 55,095 × 350 = 19,283,250	"
Heat furnished	= 6,533,250	"

Heat absorbed in chemical reactions:

De-oxidation of iron = 8,295 × 1,746	= 14,483,000	Cal.	(Absorbed).
Oxidation of carbon = 1,700 × 2,430	= 4,131,000	"	(Evolved).
" silicon = 1,000 × 7,000	= 7,000,000	"	"
" manganese = 500 × 1,653	= 826,500	"	"
Net heat absorbed	= 2,525.500	"	
Total thermal effect of furnace	= 9,058.750	"	
Heating power of coal used	= 51,000,000	"	

Thermal efficiency of combined producer and furnace:

$$\frac{9{,}058{,}750}{51{,}000.000} = 0.177 = 17.7 \text{ per cent.}$$

(C) If the furnace is merely intended to accomplish a chemical transposition, and the heat in the final product is not a desideratum, but is capable of being utilized for return to the furnace, then the net heat absorbed in the chemical reactions is the only net thermal work accomplished by the furnace.

This is so, because the energy absorbed chemically must be furnished, but the heat carried out by hot products may be more or less perfectly returned to the furnace, i. e., is not final or definitive loss.

A blast furnace reducing iron ore, for instance, reduces the ore by means of carbon, or carbon monoxide, whereby a large amount of chemical work is accomplished. The product is liquid pig-iron, but its sensible heat is in no wise all a necessary loss—a large part of it might concievably be returned to the furnace as heat in hot blast. Similarly the slag carries out much heat, but some copper blast furnaces already use hot slag for heating their blast, so that this heat is not all a necessary loss. The gases pass out of the furnace hot, and with considerable calorific power, but their sensible heat can be utilized as well as their heat of combustion, for heating blast. Much heat is lost by radiation, but how much of this can be prevented is an unsettled question. In short, some inventor with ideas of economy, might well devise schemes for returning to the furnace a large proportion of the heat ordinarily lost by hot pig-iron, slag, gases and radiation, and the more he succeeded the more efficient his furnace would be, but the irreducible minimum, the absolutely requisite energy required for the chemical reactions, would always remain as the necessary measure of the useful thermal effect of the furnace.

Illustration 7: A blast-furnace produces pig-iron containing 3.5 per cent. of carbon, 2 per cent. of silicon and 1 per cent. of manganese, from red hematite ore, using 1 ton of coke (90 per cent. carbon, calorific power 7,000 Calories) per ton of pig-iron produced. What is the net thermal efficiency?

Solution: Letting the ton be 1000 kilograms, the coke contains 900 kg. of carbon, of which, however, 35 are necessarily required to go into the pig-iron, cutting down the available calorific power of the coke to 865/900 of its theoretical power. The heating power available is therefore:

$$7{,}000 \times 865/900 \times 1{,}000 = 6{,}728{,}000 \text{ Cal.}$$

Heat used in reductions:

Silicon	20 kg. × 7,000 =	140,000	
Manganese	10 kg. × 1,653 =	16,530	
Iron	935 kg. × 1,746 =	1,652,510	1,809,040 "

$$\text{Thermal efficiency} = \frac{1{,}809{,}040}{6{,}728{,}000} = 0.269 = 26.9 \text{ per cent.}$$

In the above calculation a few refinements have been left out, such as the heat of formation of the slag, which is positive, but usually balanced approximately by the heat required to decompose the flux. Many metallurgists are accustomed to regard the heat in slag and pig-iron as usefully applied heat, but when we consider that this heat may be utilized more or less, and if returned to the furnace would increase the net efficiency of the furnace, we see that it would be illogical to regard it as usefully applied heat. Any loss of heat which may be indefinitely reduced, or any heat, otherwise lost, which can be returned to the furnace, is not net useful thermal work.

Thermal Efficiency (Class 2.)

The second class of operations, which do not admit of calculations of absolute thermal efficiency, are those in which a furnace is kept up to heat for an indefinite time, during which physical or chemical changes take place in the contents of the furnace. Here only relative thermal efficiencies, of one furnace to another, can be calculated. The bases for making these comparisons are either (1) the calorfic power expended to keep a given working space (cubical content of the laboratory of the furnace) at a given temperature for unit of time, or (2) the calorific power used to keep a given quantity of material at a given temperature for unit of time.

If the problem is, for instance, to keep a core-oven up to a certain temperature constantly, the fuel necessary to do so, per day, can be best calculated per cubic foot or cubic meter of useful baking space, and thus two ovens compared with each other. If, again, the question is to keep a pot full of metal melted all day, at a certain temperature, while it is being cast, let us say, into small ingots, then the fuel consumed should be calculated per unit of time and per unit of metal kept melted; thus comparisons can be instituted, but no calculations of absolute net thermal efficiency are possible.

It might be thought that in cases such as those just cited a quantity analogous to net thermal effect might be obtained by suddenly drawing the fire and determining the rate at which the melted metal cooled. Multiplying its fall of temperature per minute by its weight and specific heat, a value is obtained representing the heat which the bath must have been receiving

per minute in order to keep it constantly at the required temperature, and therefore the net thermal effect produced per minute by the furnace. But this quantity is not an irreducible minimum, representing net thermal effect, for by putting a thicker non-conducting lid on the pot, the bath would cool much slower, and therefore we would be led to say that the net thermal effect was smaller, whereas the relative effectiveness of the furnace would be thereby increased.

This class of operations cannot be solved by the device of Mr. Queneau, who in his recent book on "Industrial Furnaces" says that the efficiency is to be measured by the ratio of heat radiated by the body of the furnace to the total heating power of the fuel. If that were so, very thin walls, which would increase greatly the heat radiated by the body of the furnace, would increase the efficiency of the furnace (!)

ECONOMIC EFFICIENCY.

This most general aspect of efficiency is a complex quantity; for, granted that the work is properly done, the cost of operation is composed of the following factors:

(a) Cost of fuel.
(b) Cost of repairs.
(c) Cost of labor and superintendence.
(d) Cost of power, light and general supplies.
(e) Depreciation.
(f) Interest on first cost.
(g) Interest on value of material being treated.
(h) Rent of necessary ground and building.

We will consider these items *seriatim.*

(a) If a furnace is run continuously the fuel required per unit of time, or if run discontinuously, the fuel required for unit of charge treated, might equally well be supposed to measure the efficiency of the furnace in regard to fuel. The proper basis of comparison, however, between two furnaces must be on the basis of unit amount of material treated or of useful effect produced. Here we must distinguish between the cost of the fuel and the quantity of the fuel. One furnace may need 1 ton of $5.00 coke to smelt 10 tons of ore, while another may use 1½ tons of $2.50 coal to do the same work, and the latter be therefore the most efficient of the two, in re-

gard to cost of fuel. The water-jacketted copper blast furnace and the rival reverberatory smelter will well illustrate this point. If two furnaces can use the same fuel, the weights used by each in doing a given work can measure their relative fuel efficiencies.

(b) The cost of repairs per year divided by the tonnage treated per year, yields a figure which is often highly important in determining the efficiency of a furnace. Many moving parts, poor design, too light construction, too heavy walls, too expensive machine work to replace if broken, will all count in making a heavy repair bill. This item of repairs per unit of output should be distributed over a considerable period, so as to cover all kinds of periodically-occurring stoppages due to general inefficiency of the furnace.

(c) Labor forms often the largest single item in the expense account. Two furnaces may accomplish almost exactly similar results, and yet one require twice or even more laborers than the other, or one require highly skilled (and therefore high-priced) attention, while the other requires only moderately skilled labor in order to do just as good work. One of the chief items of economy in modern metallurgical practice is the great increase in the size of furnaces, by which the labor expense per unit of product is almost invariably greatly reduced, —in some cases to a small fraction of its former cost. If one highly-skilled superintendent controls the manufacture of 1000 tons of steel per day, at a yearly salary of $5000, the cost of this skilled attention is much less per ton of steel than in a mill where a $2000 man superintends the production of 200 tons daily. Such economies are possible, where, for instance, the first plant possesses 20 50-ton furnaces, and the second 20 10-ton furnaces.

(d) Two furnaces may do equally good work, with the same fuel and cost of repairs, labor and superintendence, and yet cost very differently as requires motive power, light and other supplies, such as oil, belt grease, etc. These all have their bearing on the efficiency of the furnace.

(e) Although constant repairing will keep a furnace together for a long while, yet a time comes sooner or later when it has to be practically rebuilt. Foundations will eventually sink, buck-staves rust where embedded in the ground, the hearth

get past repairing, and the roof *hors du combat*. This general re-building may come once in five years or once in fifteen, but the oftener it does come the less efficient the furnace must be regarded. Charging as depreciation 5 to 20 per cent. per year, on the first cost of the furnace, according to the life of the furnace, and dividing by the tonnage per year, there is obtained the proper depreciation cost per ton of output.

(f) Interest on cost of the furnace, at say six per cent. a year, is a proper charge, because of two furnaces doing equally good work, that one is most efficient which cost the least; and the only way to properly enter this item in the comparison of the two furnaces is to charge the interest cost per ton of material treated. Expensive castings or machine work, high-priced linings or special shapes of bricks, deep excavations, or high chimneys, all add greatly to first cost, and entail high capital charges.

(g) Two furnaces may do work of equally good quality, and turn out practically the same average output per day, and yet one furnace may keep the material in course of treatment only an hour, another a week. Or, putting it another way, one furnace may contain in course of treatment, ten tons of material and another one hundred tons, and yet the average daily output and working charges be the same per ton for each. In such cases, an interest charge on the material under treatment is a proper item in the cost sheet, in order to get a numerical expression for this difference of efficiency of the two furnaces. An ordinary 50-ton open-hearth furnace turns out 100 tons of steel per day; a Talbot continuous furnace turning out the same amount has 200 tons of steel under treatment continuously, so that the interest charge on material under treatment would be twice as great in the second case as in the first. An ordinary reverberatory roasting furnace will turn out say ten tons of roasted ore per day, the ore not being in the furnace over 24 hours; roasting stalls to roast 150 tons in 15 days (an average of ten tons per day) require that the ore be under treatment 15 days. The interest charges on value of ore under treatment is fifteen times as heavy for the stalls as for the reverberatory furnace; and in this regard the latter is much the more efficient style of roasting furnace. Smelters of the more valuable metals, particularly of copper, silver and gold, pay

particular attention to these interest charges, as they sometimes are the main factors in the total efficiency of the furnaces used.

(h) The necessary ground space and building for housing a furnace is often very different for two furnaces of the same output. Where space is at a premium, it is important that a furnace occupy small ground space, and the more compact furnace is the most efficient in this respect. A Stetefeldt furnace for chloridising roasting of silver ores will, for example, roast 80 tons in 24 hours, and occupy a space of 55 square meters; while reverberatory furnaces for the same output would occupy 700 square meters, and need a building of that size to cover them. It is correct, therefore, to add the rent of necessary ground, or ground and building, calculated per ton of output, to the cost sheet, in order to properly compare the efficiencies of furnaces.

(i) To all the above items should be added a term which cannot be expressed in dollars and cents, but only in words; viz., general reliability. The furnace which does the most uniform work, with the least brain fag for the superintendent, and which can be counted on as always doing its work, is preferable, and usually preferred, to the one which may do its work a little more cheaply but is not so reliable.

PRODUCTION OF BISMUTH IN 1905.

The marketed production of bismuth ore in 1905 was 24,405 pounds, valued at $4,187; in 1904 it was 5184 pounds, valued at $314. There was no marketed production of bismuth ores in the United States during 1903 or 1902. Interesting features in the bismuth industry in 1905 were the shipment of ore from a new deposit in California, the resumption of mining on the Ballard property in Colorado, and the reduction of 50 per cent. in the price of the metal in London from 10 s. ($2.43) to 5 s. ($1.22) a pound.

PRODUCTION OF ZINC IN 1905.

The production of zinc in 1905 showed an increase in quantity as compared with 1904, 1903, 1902 and 1901, the production being 203,849 short tons, as compared with 186,702 short tons in 1904, with 159,219 short tons in 1903, with 156,927 short tons in 1902, and with 140,822 short tons in 1901. The value of the zinc production in 1905 was $24,054,182, as compared with $18,670,200 in 1904, with $16,717,995 in 1903, with $14,625,596 in 1902, and with $11,265,760 in 1901.

ELECTRICAL SECTION.

(Stated meeting held Thursday, December 27th, 1906.)

The First Atlantic Telegraph Cable.*

BY JOHN MULLALY.

September 1, 1858, was an eventful day in the municipal history of New York, for on that day the city celebrated the landing of the first Atlantic Telegraph Cable, by which the long-talked of and eagerly-desired electric communication was effected between America and Europe, between the New World and the Old.

The popular enthusiasm, which had been increasing from day to day, after the wondrous tidings had reached New York and had been flashed over the wires to the utmost boundaries of the Republic, that "the Impracticable Enterprise," as it was stigmatized, had become a reality, culminated in one of the grandest of popular demonstrations that had ever taken place in the Empire City. All classes united in the celebration. As for the press it surpassed all previous efforts. It was indefatigable in the collection of the minutest items, and its headlines were marvels of composition and typographical display. Thus it was announced, in the biggest of capitals, that "the Cable Carnival" had attracted "Half a Million of Visitors from Afar and Near,"—a vast multitude for that day;—that the "Metropolis was literally overwhelmed with the huge crowds;" that the celebration was a "Glorious Recognition of the Most Glorious Work of the Age;" and so-forth through the column or more following the laudatory captions.

As to the public procession, the metropolis never saw anything comparable with it before. It was the largest, the most

*Read by title.

varied and the most picturesque. The civic and military authorities co-operated in the work of organization, in which the public participated heart and soul, all the associations, trade societies, clubs and kindred bodies contributing their efforts to make the celebration in every way worthy of the occasion. In the line the place of honor was, of course, given to the officers and crews of the Telegraph Squadron. At night the city was illuminated and the City Hall, which was almost hidden under a profusion of banners and flags and streamers and bunting, fashioned into folds and festoons of every conceivable form, glowed with the light of thousands of gas jets and colored lamps. Conspicuous among the distinguished persons in the procession besides the Mayor and other chief officials of the municipality, were Mr. Cyrus W. Field, Professor Morse, the inventor of the electro-magnetic telegraph; Captain Hudson, of the U. S. Steam Frigate Niagara, and the captains of the two British ships, the Valorous and the Gorgon, which, after the landing of the cable, accompanied our vessel from Newfoundland to New York.

In addition to the illumination there was a torchlight procession of the firemen, with their massive hand-engines, hose-carts and ladder trucks, making one of the most striking, as it always was one of the most popular, features in all public demonstrations. The shipping in the harbor presented an animated spectacle with its endless array of flags and streamers of all sizes and colors, among which could be distinguished the national emblems of nearly every maritime power.

The celebration, however, was not limited to the outdoor display, for there were few associations, or clubs, or other organizations of note that did not manifest their appreciation of the event by some special festivity or entertainment. The grand municipal banquet, at which the guests were numbered by thousands, and which took place in the Crystal Palace, then occupying the site now known as Bryant Park, fittingly closed the celebration of this historic episode.

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From the 5th of August, 1858, the day on which the cable was landed, to that on which the celebration took place, numerous dispatches had been transmitted through the line from

the two stations, among which were those conveying the congratulations of Queen Victoria and President Buchanan on the accomplishment of the work by the ships of the two nations. According to the official report the total number of messages sent from station to station was three hundred and sixty-six, of more or less importance. Hardly, however, had four weeks elapsed before the electrical connection had ceased altogether; the defects which had been the cause of the many delays and difficulties encountered on the different expeditions having not only impaired, but finally destroyed the continuity.

But, notwithstanding the failure of the first cable, the important fact that the paying-out process was a mechanical success and that a machine had been devised and constructed that had proved equal to the task, inspired the company with such confidence that the required amount necessary for the renewal and prosecution of the enterprise in 1866 was ultimately secured and another and more efficient cable was laid. For this renewal of the work the company was indebted mainly to the one man, Cyrus W. Field, who throughout the whole history of the enterprise was its guiding spirit. His indomitable energy and resolution overcame all obstacles, and he manifested his absolute faith in the great project by subscribing $500,000 of the original capital of $1,750,000. Among the principal American subscribers to the stock besides Mr. Field, were Mr. Peter Cooper, Mr. Chandler White, Mr. Marshall O. Roberts, Mr. Moses Taylor and Archbishop Hughes.

The first cable, as stated, had not only ceased to work, but every attempt to raise it proved futile, and it was finally abandoned.

The writer of this article had the good fortune of participating in the first Atlantic Telegraph Expeditions, those of 1857 and 1858. In 1857 he held the temporary position of secretary to Professor Morse, and the following year acted in the same official capacity to Mr. Field, Mr. Morse not taking an active part in the subsequent operations and therefore not present on the last expedition. In these relations, as well as through being the guest of the officers of the Niagara during the several expeditions, covering altogether a whole year, he had unusual opportunities and advantages for obtaining infor-

mation of the most accurate and reliable character in regard to the enterprise and the details of the work.

The following account of the first Atlantic Telegraph Expeditions can therefore be relied upon as being from the pen of an eye-witness who was personally cognizant of all he has described:

A company was organized in the month of March, 1852, under the title of the "Newfoundland Electric Telegraph Company," for the purpose of establishing communication between Europe and America. The manner in which it was to be accomplished was through a line of telegraph constructed across the southern part of Newfoundland extending from Cape Race at its eastern extremity to Cape Ray at its western, and connecting Cape Ray with Cape Breton by a submarine cable across the Gulf of St. Lawrence. The telegraphic communication with the United States was to be effected by a line from Cape Breton to Prince Edward Island, across the strait which divides that island from the mainland to New Brunswick, and thence on to the United States through the various telegraph lines and connections already established. Such, in brief, was the plan by which it was proposed to connect St. Johns with all parts of this country and the British Provinces. The communication with Europe was to be completed by the steamers that plied, or were to ply, between Great Britain and the United States.

But the company by which all this was to be accomplished was unable, for want of that wherewithal without which neither the great nor the petty affairs of the world can be transacted, to carry out their designs. Their resources were unequal to the undertaking, and after a long but ineffectual struggle they sank into hopeless bankruptcy. True, they had a charter, but they were unable to fulfil its obligations, or meet its requirements, and thus lost all the privileges and grants which were to be conferred on the successful termination of the project. Under these circumstances application was made to Mr. Matthew D. Field, and through him to his brothers, Mr. Cyrus W. and Mr. David Dudley Field, to carry on the work which the insolvent company was obliged to abandon.

Both these gentlemen took the subject into earnest consideration, and Mr. Cyrus W. Field, who had in view the sub-

merging of a cable between Ireland and Newfoundland, wrote to Professor Morse and to Lieutenant Maury, Superintendent of the National Observatory, and author of "The Physical Geography of the Sea," in regard to the practicability of the undertaking. From the first of these distinguished scientists he received the most satisfactory and encouraging assurances in regard to the electrical character of the enterprise; and Lieutenant Maury's reply in relation to the nautical part was no less gratifying and hopeful.

Thus assured by the highest authority, the great task was commenced, and though the man to whose energy and tenacity of purpose the world is mainly indebted for the success of the enterprise was fully aware of the almost insuperable difficulties he would have to encounter, he entered upon it with a determination that overcame all obstacles.

A new company, however, had to be organized and a new charter obtained before they could enter on the practical part of the undertaking; it was, therefore, decided to solicit the co-operation of capitalists whose resources and financial ability would be equal to the magnitude of the work and whose reputation would constitute the best evidence and the most substantial proof of their earnestness and sincerity of purpose. This was regarded as of the first importance to inspire the public with the desired confidence in the integrity of the company. Such co-operators Mr. Field found in Mr. Peter Cooper, Mr. Moses Taylor, Mr. Marshall O. Roberts and Mr. Chandler White. The plans and prospects of the organization were laid before these gentlemen and discussed at four successive meetings in the residence of Mr. Field, and it was finally resolved that a committee of three, consisting of Mr. Cyrus W. Field, his brother, Mr. David Dudley Field, and Mr. Chandler White (who died before the completion of the work of which he had been not only an enthusiastic but efficient advocate) should proceed at once to Newfoundland and procure a charter from the Government of that Colony. As a preliminary step, however, the new company paid off the debts of the old, amounting to about fifty thousand dollars, purchased all its property and in return received the charter under which that company was incorporated.

The agreement by which the Electric Telegraph Company

surrendered their rights was signed on the 10th of March, 1854, and four days after the Committee of Three started for St. John's, Newfoundland.

It is not necessary, for the purposes of this narrative, to enter into particulars regarding the progress and results of their mission; it is sufficient to know that they were cordially welcomed, and their application was as promptly entertained and acted on by the colonial authorities as the nature of the case would permit. The most liberal and generous spirit was manifested in the granting not only of the rights and privileges specified in the charter, but in the substantial and valuable concession of lands and subsidies, including the exclusive right of landing telegraph lines on the shores of the island and other lands within their jurisdiction, comprising, in addition to those of Newfoundland, the whole Atlantic coast of Labrador from the entrance of Hudson's Straits to the Straits of Belle Isle. The company also obtained in May, 1854, an exclusive charter from the Government of Prince Edward's Island, and afterwards from the State of Maine, and a charter for telegraph operations in Canada.

Thus far the efforts of the New York, Newfoundland and London Telegraph Company had been successful and the prospects were very promising, but the practical part of the work was still untouched and as it came to be contemplated in all its vast proportions, filling the minds of its projectors with the uncertainties and anxieties of an untried problem, a problem which some scientists regarded as impossible of solution, it might well seem to the great multitude the impracticable scheme of mere enthusiasts and visionaries; or, if not worse, the insidious designs of corrupt speculators on the gullibility of a too confiding public.

But the men at the head of the enterprise had calmly considered the chances of success; they had measured the difficulties with which they would have to contend and regarded with hopeful minds the facilities which nature herself presented to encourage its prosecution. They had been told by the highest scientific authorities that at the bottom of the stormy ocean which lay between Ireland and Newfoundland, the two island outposts of the New and Old World that were to form the points of connection, there was a vast submarine plain, an

extended plateau, on which reigned the silence of the grave and the darkness of night, where the remains of minute forms of life, so minute as to be imperceptible to the unaided vision, had lain undisturbed for untold centuries; where currents were not, and where the storms that swept over the surface two miles above, and lashed the angry waters into foam, were unknown except by the wrecks and lifeless forms with which they strewed the depths. There, in the language of the inspired writer, was the path which "the bird hath not known, neither hath the eye of the vulture beheld it, the children of the merchant have not trodden, neither hath the lioness passed by it." There the cable might lay undisturbed for centuries, and the only change would be that produced by those subtle chemical agencies which are never at rest, and which by the combination of the protecting iron with the corrosive elements of the sea, would enclose and surround it with a concrete mass, affording it a still better protection than it had received before from its outer wire covering.

What matter how much geologists may differ as to the causes which have produced this submarine plateau, this table land of the ocean, and who really cares whether it was built up by the disintegration of rocks borne down innumerable ages ago from Arctic mountains by gigantic icebergs, or by those infinitesimal shells which have been brought up from its surface by the sounding leads of Lieutenant Berryman and Captain Dayman, the two distinguished officers of the American and British Navies, who made the surveys under the orders of their respective governments. That is a question for further scientific research, and so it may be left. It is sufficient for us to be assured that it is the safest and best resting place for the cable.

On the 19th of July, 1856, Mr. Field sailed for England for the purpose of enlisting the aid of English capitalists, and in the course of three weeks, during which he had addressed large and influential meetings in Liverpool, Manchester and London, he obtained all the capital required. The organization of a corporation entitled the "Atlantic Telegraph Company" followed; and everything seemed to conspire in favor of the enterprise. Through the same indefatigable agent a contract was made with the Governments of Great Britain and the United States, by which both agreed to furnish ships for the

laying of the cable, and when that was done to pay an annual sum of seventy thousand dollars each for the transmission of official messages.

Everything was now ready for the mechanical part of the work. A cable connecting Cape Breton with Newfoundland had been laid across the Gulf of St. Lawrence, and the land line over the southern part of the latter island had been constructed. The great cable, itself, was not yet done, but the manufacturers at Birkenhead and Greenwich had promised to have it completed in time for the expedition, which was to sail in the summer of 1857.

(*To be continued.*)

Erratum.

(*Journal,* January, 1907, p. 33.)

Art: Hoge, Independent Telephone Development. For Fredericksdorf, near Hamburg, Germany, *read* Frederichsdorf, near Homburg vor der Hoehe, Germany, as the place where Philip Reis made his experiments with the telephone.

Sections.

ELECTRICAL SECTION.—Stated meeting held Thursday, November 8th, 8 o'clock. President Thomas Spencer in the chair. Present, sixteen members and visitors.

The paper of the evening was read by Albert F. Ganz, Professor of Electrical Engineering in Stevens Institute, on "The Physical Meaning of Power Factor and the Significance of a Power Factor Less than Unity without Phase Difference."

The paper was freely discussed. The speaker received a vote of thanks for his interesting communication and the meeting was adjourned.

RICH'D L. BINDER, *Secretary.*

Stated meeting held Thursday, November 22d, 1906. President Thomas Spencer in the chair. Present, forty-two members and visitors.

The paper of the evening was read by Mr. James B. Hoge, President of the International Independent Telephone Association of America, who spoke on "Independent Telephone Development."

The paper was discussed by Messrs. E. A. Scott, W. C. L. Eglin, H. F. Colvin and others.

The thanks of the meeting were voted to the speaker

Adjourned.

WM. H. WAHL, *Sec'y pro tem.*

Section of Photography and Microscopy. The 40th meeting of the Section was held on Thursday, December 6th, at 8 P.M. Dr. Henry Leffman in the chair. Present, twenty members and visitors.

The first communication of the evening was read by Mr. J. W. Ridpath on "Pictorial Composition for Beginners in Photography."

The author gave an interesting resumé of the points necessary for pictorial composition, and illustrated his remarks by the exhibition of a number of characteristic lantern views.

Mr. U. C. Wanner exhibited and commented on a number of interesting pictures of animal studies and described the method of making the same.

The thanks of the meeting were voted to the speakers. Adjourned.

M. I. Wilbert, *Sec'y.*

Mechanical and Engineering Section. *Stated Meeting,* held Thursday, December 13th, at 8 o'clock P.M. Mr. Chas. Day, President, in the chair. Present, twenty-five members.

The paper of the evening was read by Mr. Henric V. von Z. Loss, M.E., member of the Section, on "The Art of Manufacture of Railway Car Axles."

Mr. Loss took up in detail the various methods which have come into commercial use for the manufacture of railway axles, and some of the improved methods which have been tried from time to time, and then described and illustrated by a model a forging press for producing axles. This press operated on the well known principle which Mr. Loss has used in his I-bar forging process.

The paper was discussed by Messrs. Christie, Colvin, Church, Hunsberger, Derbyshire and the author.

On Mr. Christie's motion, duly seconded, the subject was referred to the Committee on Science and the Arts for investigation and report.

The meeting passed a vote of thanks to the speaker of the evening, and was adjourned.

Francis Head, *Sec'y.*

Mining and Metallurgical Section. A regular meeting of the Section was held on Thursday, December 20th, at 8 P.M. Mr James Christie in the chair.

The paper of the evening was read by Prof. Joseph W. Richards, of Lehigh University, on "Furnace Efficiencies."

It was freely discussed by Messrs. Carl Hernig, C. J. Reed, James Christie, the author and others, and is referred for publication.

The speaker received the thanks of the meeting for his able and interesting presentation of the subject, and the session was adjourned.

W. J. Williams, *Sec'y pro tem.*

Book Notices.

Annuaire pour l'an 1907 publié par le Bureau des Longitudes avec des notices scientifiques: Paris, Gauthier-Villars, n. d. 900 pages, illustrations, 16mo., paper. Price, postage paid, 1 franc, 85c.

The little book contains much information which is useful to the engineer and man of science. The special articles of the present issue are by M. A. Bouquet de la Grye on the diameter of Venus and M. H. Deslandres on the history of conceptions and of the researches regarding the sun.

Self-propelled Vehicles: A practical treatise on all forms of automobiles, by James E. Homans, A.M. Fifth revised edition, entirely re-written. 598 pages, illustrations, plates, 8vo. New York, Theo. Audel & Co. 1907. Price, $2.00.

New and completely revised, this work fulfills the requirements of the motor vehicle owner, operator and repairer. In his revision the author has emphasized the practical aspects of motor vehicles of all powers, confining his space to the discussion of matters fundamental in construction and management. Recognizing that the gasoline vehicle is the typical automobile, considerable space is devoted to its complete discussion, theory, operation, and an extensive chapter on "Gasoline Engine Management," the latter covering, virtually, all forms of difficulty liable to occur under service conditions.

All the accessory parts of an automobile, carburetters, igniters, transmission gears, are fully explained by typical examples. The author properly assumes that an adequate knowledge of the principles upon which these devices are constructed will enable the reader to understand variations for himself.

Second Report of the Wellcome Research Laboratories at the Gordon Memorial College, Khartoum. Andrew Balfour, M.D., B Sc. Khartoum, Department of Education, Sudan Government, 1906. 255 pages, illustrations, colored plates, 4to.

The present report gives an outline of the progress made in dealing with malaria, sleeping sickness and the various other tropical diseases in the Sudan. There are also a number of original articles on the insect pests which attack food and textile-producing plant life. The numerous illustrations, especially the full-page plates of flies, in colors, are excellent.

Penrose's Pictorial Annual: The Process Year Book for 1906-7. Vol. 12. Edited by William Gamble. 160 pages, illustrations, 8vo. London, A. W. Penrose & Co., Ltd. American Agents, Tennant & Ward, New York. Price, $2.50.

For twelve years this popular annual has been making its appearance. Each year it grows in size and in value. All who are interested in any way in the graphic arts will find this work useful.

There are many excellent examples of half-tones, two- and three-color prints, collotypes, line etchings and photogravures. The reading matter is as varied and interesting as heretofore.

PUBLICATIONS RECEIVED.

Otis Elevator Company. Catalogue illustrating and describing, in general, elevating machinery and apparatus. 62 pages, illustrations, 8vo. New York, 1905.

Life Insurance: The Abuses and the Remedies. An address delivered before the Commercial Club of Boston, by Louis D. Brandies. 27 pages, 8vo. Boston, Policy-Holders Protective Committee, 1905.

Nature Study and Gardening. Primary methods and outlines for the use of teachers in the Indiana Schools. 27 pages, illustrations, plates, 8vo. Washington, Government Printing Office, 1905.

Philippine Journal of Science, Vol. I. No. 1, January, 1906. Edited by Paul C. Freer, M.D., Ph.D. Co-Editors, Richard P. Strong, M.D., and H. S. McCackey, B.S. Published by the Bureau of Science of the Government of the Philippine Islands. Manila, Bureau of Printing, 1906. Contents: Papers on the Cocoanut Palm and the Cocoanut, by Paul C. Freer, Edwin Bingham Copeland and Herbert S. Walker; The Occurrence of Schistosoma Japonicum vel Cottoi in the Philippine Islands, by Paul G. Woolley; A Study of some Tropical Ulcerations of the Skin, with Reference to their Etiology, by Richard P. Strong. 115 pages, illustrations, plates, 8vo.

Annual Report of the Secretary of the Navy for the year 1905. 54 pages, 8vo. Washington, Government Printing Office, 1905.

Report of the Chief of the Bureau of Ordinance to the Secretary of the Navy, 1905. 48 pages, 8vo Washington, Government Printing Office, 1905

Tonindustrie Kalender, 1906. Three parts, illustrations, 24 -mo. Berlin, Verlag der Tonindustrie Zeitung.

Doble tangential water wheels, Doble patented needle regulating nozzles, Doble patented ellipsoidal buckets, Doble high-speed ring-oiling bearings, manufacturd by Abner Doble Company, engineers, San Francisco. Bulletin No. 7, 1906. 100 pages, illustrations, 8vo.

U. S. Coast and Geodetic Survey, Terrestrial Magnetism. Results of magnetic observations made by the Coast and Geodetic Survey between July 1, 1904, and June 30, 1905, by L. A. Bauer,, inspector of magnetic work. Appendix No. 3, Report for 1905. 85 pages, 4to. Washington, Government Printing Office, 1905.

Teachers' Sanitaty Bulletin, published monthly by the State Board of Health, Lansing, Michigan. Volume 8, Nos. 7, 8, 9, July, August, September, 1905.

Report of the Superintendent of Indian Schools to the Commissioner of Indian Affairs for the year ending June 30, 1905. 34 pages, plates, 8vo. Washington, Government Printing Office, 1905.

Koenigliches Materialpruefungsamt der Technischen, Hochschule, Berlin. Bericht ueber die Taetigkeit im Betriebsjahre, 1904.

Sonderabdruck aus den Mitteilungen aus dem Koeniglichen Materialpruefungsamt Gross-Lichterfelde West. 1905. 50 pages, 8vo.

The Irrigation System of Ontario, California, its development and cost, by F. E. Trask, with discussion by Messrs. Arthur S. Hobby and F. E. Trask. Reprinted from the Transactions of the American Society of Civil Engineers, Vol. 55, page 173. 10 pages, illustrations, plates, 8vo. Issued by the Abner Doble Co., San Francisco, Cal., as Bulletin No. 9.

The Franklin Institute.

(Proceedings of the Annual Meeting held Wednesday, January 16th, 1907.)

HALL OF THE INSTITUTE,

PHILADELPHIA, PA., January 16th, 1907.

PRESIDENT JOHN BIRKINBINE in the chair.

Present, twenty-three members.

The Annual Reports of the Board of Managers and of the various Committees of the Institute and the Board. Also the Annual Report of the Trustees of the Elliott Cresson Medal Fund were presented and accepted, and directed to be published.

The tellers of the Annual Election made their report showing the election of all the candidates nominated at the stated meeting of December 19, 1906. The President thereupon declared the nominees duly elected to their respective offices. The tellers received a vote of thanks.

President Birkinbine thereupon introduced Mr. F. H. Newell, of the U. S. Geological Survey, Washington, D. C., who presented a paper, profusely illustrated with lantern photographs, on "The Work of the Government Reclamation Service." In this communication, Mr. Newell gave a description of a number of the more important engineering works that had been executed and of a number at present under way, designed to reclaim, for the purposes of agriculture, many thousands of acres of arid and semi-arid lands in the far West.

The speaker received a vote of thanks.

The retiring President, Mr. Birkinbine, thereupon introduced President-elect Mr. Walton Clark, who, after expressing his appreciation of the honor conferred upon him, assured the members of his complete devotion to the promotion of the interests of the Institute.

Adjourned.

WM. H. WAHL, *Secretary.*

Report of the Board of Managers for the Year 1906, with Appendices Embracing the Annual Reports of Committees and Sections.

To the Members of the Franklin Institute:

The Board of Managers submit for your consideration this report and accompanying appendices covering the work of the Institute during its eighty-second year of usefulness.

During 1906 the two hundredth anniversary of the birth of Benjamin Franklin was celebrated in Philadelphia with impressive ceremonies, at which your President represented the Institute. Recognition of the anniversary was also made by the Institute in a series of special papers read at

the monthly meetings, and subsequently published in the *Journal*, which presented the life and works of Franklin in an instructive and interesting manner.

More pretentious ceremonies had been contemplated, but these were omitted so that the Franklin Institute should not appear as interfering with the commemorative functions outlined by the American Philosophical Society, which claims Franklin as its founder.

The Board also regrets that owing to the impossibility of securing the buildings, for the use of which arrangements were in progress at the last report, the exhibition suggested as a fitting celebration of the Franklin Bicentennial had to be abandoned.

During the year a special committee has succeeded in making progress towards securing for the Institute a new home, where in a more desirable location, and with improved facilities, it can keep pace with the progress of a great city and a great country. Upward of One Hundred Thousand Dollars have been pledged towards this object, and the committee is endeavoring to increase this fund to Two Hundred and Fifty Thousand Dollars. Chances for success will improve as subscriptions from members and friends grow in amount.

An appeal may properly be made to those who have benefitted by the Franklin Institute work, urging their assistance in securing funds to erect a new and well-equipped building which will be conveniently situated.

The report of the Library Committee shows that the Institute now has 60,248 volumes, and in addition pamphlets, maps, charts, etc., some of them unique, which make an aggregate of 109,263 titles, in fact, an unexcelled technical library which cannot be used to the best advantage because of the limited space and restricted income.

The report of the Committee on Instruction emphasizes existing conditions, under which the 598 pupils received instruction in the night schools of drawing, machine design, and naval architecture, and records the fact that owing to the limitations of our buildings some of the lecture courses have to be presented in conjunction with the Young Men's Christian Association in its Auditorium.

Ten meetings of the Institute and twenty-six sectional meetings, held during the year, were rich in contributions and discussions upon Physics, Chemistry, Electricity, Mining, Metallurgy, Engineering, Photography, Microscopy, and other specialties, many of which have appeared in the *Journal of the Franklin Institute*, our Institute publication, which has a world-wide reputation.

The Committee on Science and the Arts considered sixty-one applications for award, and granted during the year eleven medals and one certificate of merit. It also made three advisory reports and dismissed six applications.

When it is remembered that the labors of the members of this committee, as well as those of all the Institute and Board Committees, are gratuitous, that the services of most of the lecturers are given without compensation, and that such unselfish work has characterized the Franklin In-

stitute for eighty-two years, it would seem that the Institute's claim for support should meet a ready response.

The financial statement which exhibits the condition of the Institute also shows that the total endowment, including funds devoted to special purposes, aggregates $140,000, a sum far below what an organization should command to carry forward the work which the Institute should assume; in fact, the income from invested funds will not properly sustain the Library.

During the year an application has been made for the Uriah A. Boyden Premium of $1,000 to be awarded to one who shall demonstrate whether light and other physical rays are, or are not, transmitted with the same velocity. The application is being considered by a special committee.

Death removed during the year two members of the Board of Managers, Mr. R. C. H. Brock, who served from 1901 to 1906, and Mr. Samuel Sartain, who sat on the Board for forty-one consecutive years. Since 1882 he has been the Treasurer of the Institute. The *Journal* has published a fitting obituary of Mr. Brock, and a committee will prepare a suitable memorial of Mr Sartain, but it is eminently proper that this report should include a minute of the great service rendered the Institute by its late Treasurer.

The Board has properly acknowledged donations which have been made to the Institute, all of which are fully recorded in its minutes.

The membership roll now numbers 1,532, of which 830 are resident and 702 are non-resident members.

John Birkinbine,
President.

Philadelphia, Pa., January 9, 1907.

FINANCIAL STATEMENT FOR 1906.

The annual report of the Treasurer for 1906 shows:

Balance January 1st, 1906	$ 653.70
Total receipts	33,452.79
	34,106.49
Total payments	33,700.42
Balance January 1st, 1907	$ 406.07

REPORT OF THE LIBRARY COMMITTEE FOR THE YEAR 1906.

To the President and Members of the Franklin Institute:

The Committee on Library respectfully submits the following report:

The additions to the Library during the year 1906 comprised 1,793 titles, as against 2,132 in the preceding year and 2,397 in 1904.

The new acquisitions include:

872 bound volumes,
285 unbound volumes,
566 pamphlets,
12 charts,

1 manuscript,
57 drawings,

These accretions were derived from the following sources:

71	through	the	Bloomfield Moore Fund,
2	"	"	Memorial Library Fund,
63	"	"	M. Carey Lea Fund,
17	"	"	James T. Morris Fund,
38	"	"	general library appropriations,
192	"	"	binding of periodicals,
47	"	"	*Journal* of the Institute,
34	"	"	exchange account,

and the remainder through deposits from the Federal and State Governments, through contributions from societies and institutions at home and abroad and through gifts from individual donors. Especially notable have been the contributions received from:

Drs. S. Solis Cohen and William H. Greene; Prof. Lewis M. Haupt; Mrs. Samuel C. Hooker, Mrs. Wilfred Lewis and Mrs. M. Russell Thayer; Messrs. H. M. B. Bary, John E. Carter, James S. Coates, George S. Cullen, Morris Ebert, Richard Gilpin, Henry Pemberton, Jr., Anthony W. Robinson, E. Smith, James M. Swank, and the Crocker-Wheeler Electric Company.

The pamphlet additions are again below the average, and it is due, as in former years, to the fewer gifts received from members. There is a slight increase in the number of volumes purchased during the year, though the Committee is still following out the policy of utilizing the various library funds for the purchase of large and more important reference works, which are naturally sought in the collection of a special technical library. It is in this direction that the Committee finds itself most hampered for the want of a greater income.

The present contents of the Library are as follows:

	60,246	volumes (bound and unbound),
	43,913	pamphlets,
	2,886	maps and charts,
	747	drawings and designs,
	1,247	photographs,
	192	newspaper clippings,
	32	manuscripts,
a total of	109,263	titles.

There are also on hand at the present time the following number of duplicates: 449 bound volumes, 134 unbound volumes and 150 numbers of periodicals. These are not included in the permanent collections of the Library as they may be disposed of by exchange or otherwise.

BINDING.

Binding and re-binding were effected during the past year as follows:

191 volumes of complete serials,
203 paper-bound books,

24 rebindings,
1 repaired,

Four hundred and thirty-six volumes are still in the binder's hands. More binding is sadly needed, and more money could be spent on binding with great advantage to the Library. The British Patent Specifications especially should be bound, since, although these documents are accessible in their present condition, it is imperative that they should be bound if they are to be permanently preserved.

PAMPHLET COLLECTION.

The pamphlets of the Library are stored on shelves on the first floor of the building in the south room. They are safe enough there, but owing to lack of classification they are practically unavailable for use. Many of these pamphlets are exceedingly valuable, and in order that they may be available to students, they should be classified and appear in the card catalogue of the Library. This work will require the services of a trained assistant for several years and will necessitate the expenditure of a considerable sum of money for wages, catalogue cards, pamphlet boxes, and incidentals.

EVENING ATTENDANCE.

The Library was open on forty-four evenings during the past year, with a total attendance of 182 visitors, an increase of twenty-one over the preceding year. While it is to be hoped that the number of evening visitors will continue to increase, it is hardly likely that any great change will occur as long as the Institute is in the present quarters.

EDWIN S. BALCH, *Chairman.*

REPORT OF THE COMMITTEE ON SCIENCE AND THE ARTS FOR THE YEAR 1906.

To the President and Members of the Franklin Institute:

The Committee on Science and the Arts has the honor to submit the following account of its operations during the year 1906:

The total number of cases on the record book for 1906 was 61, of which 41 were carried over from last year, and 20 were new cases added in 1906.

The number of cases disposed of during 1906 was 22. In two cases the Elliott Cresson Medal was awarded; six received the award of the John Scott Legacy Premium and Medal; three received the Edward Longstreth Medal of Merit; and one received the Certificate of Merit. Three reports were made advisory and six were dismissed. There were two protested cases and one supplementary report.

Appended hereto is a list of the awards.

Respectfully submitted,

HUGO BILGRAM,
Chairman of Committee for 1906.

PHILADELPHIA, PA., January 2, 1907.

APPENDIX.

AWARD OF THE ELLIOTT CRESSON MEDAL.

2351. The American Paper Bottle Company, for their "Paper Milk Bottles."
2385. Mr. William J. Hammer, for his "Historic Collection of Incandescent Electric Lamps."

AWARD OF THE JOHN SCOTT LEGACY PREMIUM AND MEDAL.

2365. C. J. Reed, for his "Speed-Jack."
2375. W. C. Heraeus, for his "Fused-Quartz Mercury Lamp."
2379. Louis H. Walter and James Alfred Ewing, for their "Method of Detecting Electrical Oscillations."
2381. Alexander Crawford Chenoweth, for his "Concrete Pile."
2384. Max E. Schmidt, for his "Moving Platforms."
2394. J. P Tirrell, J. R. Reynolds and Frederick S. Palmer, for their "Monarch Engine-stop and Speed Limit System."

AWARD OF THE EDWARD LONGSTRETH MEDAL.

2371. C. B. Weidlog, for his "Friction Indicator."
2374. Dr. G. H. Meeker, for his "Improvements in Analytical Apparatus."
2380. Wilbur I. Follett, for his "Time-Stamp."

AWARD OF CERTIFICATE OF MERIT.

2361. J. H. Hallberg, for his "Alternating Current Electric System."

REPORTS MADE ADVISORY.

2376. Victor P. DeKnight, for his "Rapid Fire Guns."
2386. Dr. L. Reuter, for his "Process for Soaps and Turpentine Derivatives."
2358. Supplementary report on Colt's Pistols.

DISMISSED.

2105. Hausemann's Knitting Machine.
2117. Paxson & O'Neill's Knitting Machine.
2193. Earl's Physiological Apparatus.
2295. Hall's Aluminum Inventions.
2296. Matthew's Photometer.
2349. Bowditch's Cotton-Picking Machine.

There is one Elliott Cresson Medal pending on account of a protest.

REPORT OF THE COMMITTEE ON MEETINGS FOR THE YEAR 1906.

To the President and Members of the Franklin Institute:

The Committee on Meetings has, as heretofore, arranged the programs of the ten stated meetings of the year. Concerning the character of the communications presented, the Committee has no special comment to make save to state that a number of them were deemed of sufficient importance

to warrant publication in the *Journal*. Among the interesting events of the past year were the meetings held in commemoration of the 200th anniversary of the birth of Franklin.

The Committee has noted with regret the continued falling off in the attendance of members at the monthly meetings, a circumstance that has received notice in previous reports.

This is due, in part, to the fact that the Section meetings divert, to some extent, the interest of the members, but probably more largely to the inconvenient situation of the Hall. This circumstance is one of many that serves to accentuate the imperative need of providing a new building for the Institute in a more convenient locality.

Respectfully submitted,

WASHINGTON JONES,
Chairman of Committee on Meetings.

PHILADELPHIA, PA., January 2, 1907.

REPORT OF THE COMMITTEE ON PUBLICATION FOR THE YEAR 1906.

To the Board of Managers:

The Committee on Publication respectfully reports that the material offered for publication has fully met its necessities, in quality as well as quantity. The Board and members have reason for congratulation in the fact that the *Journal* of recent years has become what its name implies, the Journal of the Franklin Institute, the numerous contributions to its pages by the Sections, the meetings of the Institute and its several committees, evincing the continued activity of the Institute. The contract for printing the *Journal*, entered into last year, has been continued during 1906 and the Committee is pleased to announce that the promise of substantial saving in the cost of publication has been fully realized.

H. W. JAYNE,
Chairman of Committee on Publication.

PHILADELPHIA, PA., January 9, 1907.

REPORT OF THE COMMITTEE ON INSTRUCTION FOR THE YEAR 1906.

To the Board of Managers:

The School and lecture work has been carried on during the past year along the same lines as heretofore. Twelve popular lectures, all generously illustrated, were given under joint patronage of the Central Branch of the Young Men's Christian Association, and were largely attended. The lecturers as a rule proffered their services without compensation, and the thanks of the Board are due to these gentlemen for their services.

The Schools of Drawing, Machine Design and Naval Architecture have been well patronized, the attendance of pupils being as follows:

	1906
Drawing School	272
" " (Branch School)	197
School of Machine Design	114
School of Naval Architecture	15
Total	598

Considering the very indifferent accommodations offered to our pupils, when compared with those of other institutions engaged in similar work, the large attendance speaks well for the thoroughness of their instruction and the competency of the instructors.

Respectfully submitted,

WM. H. WAHL,

Chairman of Committee on Instruction.

PHILADELPHIA, PA., January 2, 1907.

REPORT OF THE COMMITTEE ON SECTIONAL ARRANGEMENTS FOR THE YEAR 1906.

To the Board of Managers:

Your Committee has pleasure in reporting that the various Sections have displayed a gratifying amount of activity during the past year. No less than twenty-six meetings were held.

Besides the large number of scientific and technical papers, several important technical subjects were discussed, and a number of papers were read by title because of the overcrowded state of the Sections' schedules.

The major portion of the pages of the *Journal* were, and for a number of years have been, devoted to the excellent material provided by the Section proceedings, and the value of these contributions has been shown in the most gratifying manner by their frequent reproduction in the scientific and technical journals, domestic and foreign.

The contributions of the Sections are to be credited as follows:—

Section of Physics and Chemistry	7
Electrical Section	5
Mining and Metallurgical Section	4
Mechanical and Engineering Section	5
Photographic and Microscopic Section	5
Total	26

The union of the Physical and the Chemical Sections has proved to be beneficial to both bodies.

In conclusion, your Committee wishes to express its appreciation of the substantial services of the professors, lecturers, and the Section officials, in assisting in providing material for the meetings.

Respectfully submitted,

JAMES CHRISTIE,

Chairman of Committee on Sectional Arrangements.

PHILADELPHIA, PA., January 2, 1907.

REPORT OF THE COMMITTEE ON ELECTION AND RESIGNATION OF MEMBERS FOR THE YEAR 1906.

To the Board of Managers:

GENTLEMEN:—The Committee on Election and Resignation of Members respectfully submits the appended figures for the year in relation to the membership.

The systematic efforts to obtain new members have been continued, and the Committee's work supplemented by that of a few of the members of the Institute has resulted in the placing of seventy new names on the list. This number has not been sufficient to overcome the loss through death, resignation and non-payment of dues, which amounts to ninety-two. The change in the numerical strength of the Institute is noted below in figures. The members of the Institute generally are urged to second the efforts of the Committee by nominating new members. One new member per year secured by each old member, would be easily possible of accomplishment.

The membership at the close of 1905 was	1554
New members secured in 1906	70
	1624
Loss by death, resignation and non-payment	92
Members at close of 1906	1532

Respectfully submitted,

ALEXANDER KRUMBHAAR,
Chairman.

PHILADELPHIA, PA., January 1, 1907.

JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA

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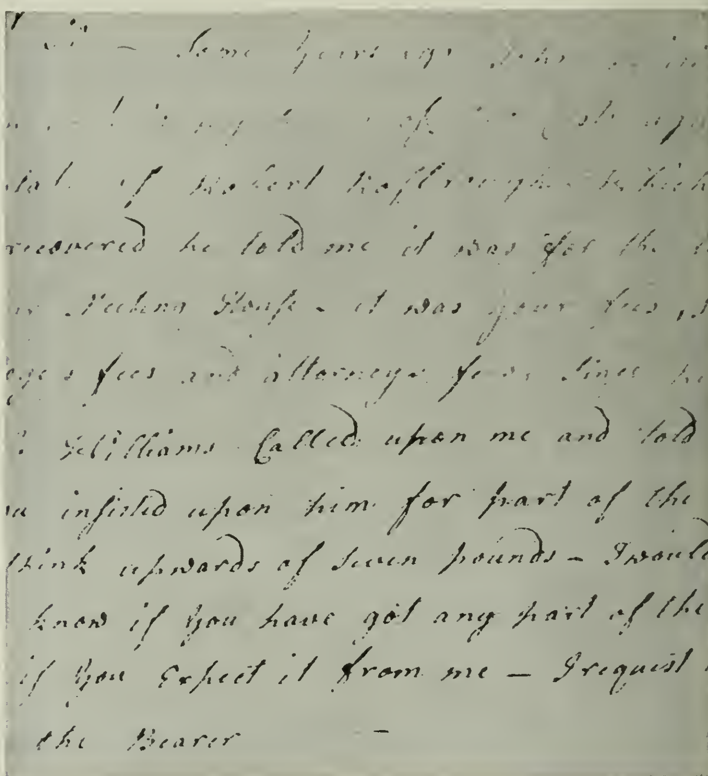
Treatment of Written Historical Documents for Preservation.

PROFESSOR CHARLES F. HIMES, PH. D.

In the preparation of old written documents for mounting and filing, it is a practice of many historical societies to remove the creases and flatten them by moistening the documents first, rather thoroughly with water, by passing a sponge or brush filled with it over the face, and then subjecting them to pressure between blotters. A sheet of less absorbent paper, as blank newspaper, is in some cases placed next to the document. Whilst in some or even many cases this treatment may not produce a perceptible change in the intensity or color of the writing, or affect its clearness, it does have in others a very perceptible effect in both respects, and it may almost be

assumed that in all it has a tendency to impair the vigor and permanency of the writing. In many cases the dampened ink will set off under the pressure onto the blotters, and whilst the writing may still be clear and legible, the hard protective outside coating of the ink will be removed, or rendered more pervious to atmospheric and other influences and a strong, vigorous writing give place to one of feebler appearance. It is


Williams Called upon me and told
insisted upon him for part of the
think upwards of Seven pounds — I would
know if you have got any part of the
if you Expect it from me — I request
the Bearer

also a pertinent question as to how far moistening the paper may affect the size and physical condition of the paper, and thus the strength and permanence of the paper as well as the writing. These remarks apply of course equally to such documents as it may be found necessary or advisable to reinforce with some light, semi-transparent fabric, as silk gauze, and in such cases it is worth considering whether reinforcement of the

weak parts, generally the folds, by strips of such material might not be sufficient and preferable. Such strips could be attached more easily, by any one, without much practice, by means of a quickly drying photographic paste, without the same effect upon the writing or paper.

Whilst with many documents of secondary importance these considerations may make little difference, with others it is a grave question whether the flattening of documents is not accomplished at considerable loss or risk in many directions, and with no corresponding gain in legibility, and most likely loss under magnification.

The accompanying half-tone of a document, one half of which was treated as described, and the other half simply subjected to pressure at the same time, will illustrate and emphasize the preceding statements. The document bears date "1789," the writing is uniformly black and distinct, and the paper in excellent condition. The print, direct from the negative, one of a lot, shows plainly the treated portion, but not as distinctly as the document itself. The document, selected from a number, was the first experimented with in this way.

It seems in place to add, that such variation in *intensity* of documents, so to speak, may be greatly reduced in the photograph, or even eliminated, in many cases by suitable photographic manipulation in the production of the negative or print.

STREAM POLLUTION BY ACID-IRON WASTES.

A discussion of stream pollution by acid-iron wastes, based on investigations made at Shelby, Ohio, has recently been published by the United States Geological Survey as Water-Supply and Irrigation Paper No. 186. The author, Mr. Herman Stabler, gives the history of the pollution and the attendant litigation, explains the effect of acid-iron liquors upon sewage purification processes, describes the conditions along the streams, and discusses methods of disposing of acid-iron wastes without discharge into watercourse or sewerage system. The investigations conducted by Mr. Stabler were made under a co-operative agreement between the United States Geological Survey and State Board of Health of Ohio, each bureau participating equally in the expenses involved.

Stream pollution by iron works effluents has always been an important question in countries where the iron industries are prominent. The polluting liquors, commonly known as "acid-iron" liquors, are derived from the "pickling process" common to galvanizing, tin plating, tube and sheet iron treatment. This "waste pickle" is not a desirable addition to streams (1) because it produces a reddish discoloration and turbidity, mak-

ing the stream waters, bed, and banks unsightly; (2) because, by reason of its avidity for oxygen, it robs the waters of their natural supply of this essential gas and thereby, when it is present in comparatively large quantities, causes the death of fish, and (3) because it gives rise to a large quantity of iron in the stream, and thereby impairs the usefulness of the water for domestic and laundry purposes and for certain manufacturing processes.

This report is for general distribution and may be obtained on application to the Director of the United States Geological Survey at Washington, D. C.

PRODUCTION OF GAS, COKE, TAR, AND AMMONIA.

A report on the production of gas, coke, tar, and ammonia at gas works and in retort coke ovens during 1905 has been prepared by Mr. Edward W. Parker of the United States Geological Survey and is now ready for distribution. It is supplementary, in a measure, to the reports on the production of coal and the manufacture of coke, and is made in response to a demand from producers of gas and coke and the by-products of tar and ammonia, for statistical information on these subjects.

The present report includes, in addition to the statistics of the production of gas, coke, tar, and ammonia at gas works and in by-product coke ovens, a statement of the production of the quantity of gas and tar produced at water-gas works using crude oil for enriching purposes. These statistics have not been considered in any of the preceding reports. At some of the gas houses oil is used with the coal in the production of gas, but the entire production is included in the statistics of coal gas.

The total quantities of these products in 1905 was 40,454,215,132 cubic feet of gas (not including that lost or wasted) 5,751,378 short tons of coke, 80,022,043 gallons of tar, 46,986,268 gallons of ammonia liquor (equivalent to 22,455,857 pounds of anhydrous ammonia), and 38,663,682 pounds of ammonia sulfate, against 34,814,991,273 cubic feet of gas, 4,716,049 short tons of coke, 69,498,085 gallons of tar, 52,220,484 gallons of ammonia liquor (equivalent to 19,750,032 pounds of anhydrous ammonia), and 28,225,210 pounds of ammonia sulfate in 1904. The total value of all these products in 1905 was $56,684,972 against $51,157,736 in 1904.

OIL AND WATER GAS.

Returns were received from 477 oil and water-gas producing companies, and these show that the total production of water gas in 1905 was 82,959,228,504 cubic feet.Of this quantity 5,547,203,913 cubic feet, or 6.7 per cent., were lost by leakage, etc., leaving 77,412,024,591 cubic feet as the net production obtained and sold. As the quantity of gas made and sold at coal-gas and by-product coke oven works was 40,454,215,132 cubic feet, it appears that the consumption of water gas, and gas made from crude oil was nearly twice as much as that made from coal. It also appears that while the average price of coal was in 1905 was 81.4 cents per 1000 cubic feet, that of oil and water gas combined was a fraction of a cent in excess of $1 per 1000 cubic feet. Still further comparison shows that whereas 66 per cent. of the production of coal gas was sold as illuminating gas, 77 per cent. of the combined production of oil and water gas was used for this purpose.

ELECTRICAL SECTION.

(Stated meeting held Thursday, December 27th, 1906.)

(Concluded from February, 1907, vol. clxiii, page 148.)

The First Atlantic Telegraph Cable.*

BY JOHN MULLALY.

And now, having arrived at this point, it is essential for a further investigation of our narrative, to consider in detail this marvelous but simple production of mechanical ingenuity, this great electric link which binds worlds together in immediate intercourse, and along whose slender copper core the subtle electric current courses with the speed of thought. The mechanical process by which the cable is produced is simplicity itself; but it is with the material of which it is composed that we have to do. In the first place the most important part of the covering is the gutta percha, a peculiar gum obtained from a tree which grows in the East Indies and which possesses not only the property of resisting acids, but which is also one of the most perfect non-conductors of electricity known to science.

Up to the time of its discovery and application to this particular use, all attempts to make a perfectly insulated submarine conductor had failed. Narrow tracts of water, it is true. had been crossed by sub-aqueous wires, but the impossibility of establishing communication between distant points separated by water had become clearly apparent.

In October, 1842, as I was informed by Professor Morse, he connected Governor's Island with the Battery by a conductor which was insulated, or covered with a coating of tar, pitch and

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*Read by title.

India rubber, and although he succeeded in passing a current through it after its submersion, he was convinced that the insulation thus effected could be only temporary. But here was a new material, the peculiar properties of which became known just at a time when science had tried all its former resources and appliances without effect.

The conductor in the center of the first Atlantic telegraph cable was composed of seven small copper wires, each of which was as thin as an ordinary pin. In this first ocean cable, to which the present description applies, these copper wires were twisted spirally, in which form, it was claimed, they were capable of being extended a considerable portion of their length before parting. Then should six of the seven part, the seventh, it was asserted, would have sufficient tenacity to maintain the electrical continuity. To insure the complete insulation of the conductor, it was covered with three layers, or coatings of gutta percha, over which was wound a serving of hemp steeped in a composition of tar and pitch. The unfinished cable next received the outer covering, or wire armor; after which it was passed through tanks of tar before being subject to the process of coiling, the tar protecting the iron from rust until submerged; but when once safely deposited on the bottom, all the corrison to which it would then be subjected could not affect the conductivity insured by the insulating property of the inner covering of gutta percha. In the manufacture of the three thousand miles of cable there would be, it was estimated, a liberal margin over and above the sixteen hundred and forty nautical miles, or nineteen hundred and fifty statute miles, which was the distance between the connecting points in Valentia Bay, Ireland, and Trinity Bay, Newfoundland.

Three thousand miles of cable were, therefore, manufactured and coiled on board the Niagara and Agamemnon by the month of July, 1857; and both ships having received the machinery required for the process of submersion, proceeded to Queenstown, Ireland, which had been selected as the place of rendezvous. From Queenstown the whole Telegraph Squadron proceeded on its course. It consisted of the two above-named principal, or cable ships; the Susquehanna (which took no part in the subsequent expedition of 1858), to at-

tend upon the Niagara; the British war steam frigate Leopard, as escort to the Agamemnon; the Cyclops, to keep the course; and two small steamers, the Advice and the Willing Mind, to assist in landing the cable in Valentia Bay. From that point it was decided that the laying of the cable should be begun, although the proposition to commence in mid-ocean met with more favor.

Advantage was taken of the time required for the passage from Queenstown to Valentia to test the machinery on the Niagara, but the trial proved so unsatisfactory that it caused considerable anxiety as to the issue.

On the 5th of August the operation of taking the cable ashore was effected in the presence of a great multitude from all parts of Ireland assembled to witness the public and official ceremonies with which the occasion was to be celebrated. It was, in fact, one of the greatest events that had occurred in the history of the country, and the enthusiasm of the people was unbounded.

The end of the cable was landed in the midst of the wildest excitement; the spectators, unable to restrain their impatience till the cable reached the shore, rushed into the water as with a common impulse, and joining the men of the Niagara, ran with it up the beach, bearing back the dense crowd that vainly endeavored even to participate in the honor of having touched it with their fingers.

In the evening there was great rejoicing in the little village of Knightstown and the merrymakers kept up the festivities throughout the night. In the morning the Niagara resumed the work of paying-out, and with her bow to the westward, proceeded at the rate of two miles an hour. This was the shore cable, and as it was much thicker and heavier than the deep sea line, the paying-out process was consequently more tedious and difficult. The misgivings felt as to the working of the mechanism were confirmed on the very first trial, which proved a signal failure, hardly two miles having been paid out before the dreaded fracture occurred; the cable had surged off from the grooved wheels of the paying-out machine, and becoming entangled, snapped like a pipe stem. Several hours were lost in repairing damages, when the work was resumed with better success.

The 7h, 8th, 9th and 10th of August saw the Niagara still laying the cable and the hopes of the desponding began to revive. All went well till the night of the 10th, when an interruption in the electric continuity occurred, lasting over two hours. It was a phenomenon which the electricians in vain tried to clear up; but in the midst of their perplexity and when they were about to give up in despair, the continuity returned as suddenly as it had disappeared. It was as inexplicably restored as it had mysteriously been interrupted.

But our rejoicing was premature; our good fortune was to be short-lived, for about a quarter to four the following morning the cable again parted in consequence of another excessive strain to which it had been injudiciously exposed; the machine was temporarily paralyzed and the broken end of the line swung loosely from the stern of the Niagara.

This time the cause of the disaster was no mystery; the engineer in charge, acting precipitately under the impression that there was an excessive expenditure of the cable, had put an undue pressure on the brakes. The result was inevitable: the wheels of the paying-out machine ceased to revolve and the cable parted under the increased strain.

There was a sad scene on board our ship when it was announced that we were to return to England bearing the depressing and mortifying news of our defeat and of the grave disaster to the enterprise. We had grown over-confident from our last four days of almost uninterrupted progress and were hopefully calculating the number of days and hours it would take to reach the bleak and mountainous shores of Newfoundland. We thought of home and of the great expectant public who were eagerly awaiting the hour that would bring them the glorious news of our success; and our hearts throbbed more rapidly as the hope grew day by day into the semblance of a living reality.

But here we were two hundred and sixty-six miles from our starting point on the Irish coast and with three hundred and thirty miles less of cable than we had on board when we steamed, four or five days before, out of Valentia Bay. As to the financial loss, it amounted to over one hundred and fifty thousand dollars for the cable alone.

Although depressed, we were hopeful of ultimate success,

for having laid so much of the line we not unreasonably concluded that but for that unlucky mishap of the strain, we might have reached our destination. Before this the gravest doubts were entertained as to the practicability of the work, for it was believed and persistently asserted by the skeptics, that it would be found impossible to submerge the cable in the great depths; but here we were above the great depths already and the broken line lay on the Telegraph Plateau two miles beneath the keel of the Niagara. Over seventy miles had been laid in water from fifteen hundred to two thousand fathoms deep when the fracture occurred, and what more convincing proof could be required of the feasibility of the undertaking?

About six o'clock on the morning of the 11th of August a meeting was called in the cabin of the Niagara, at which the engineers, the electricians and the Commanders of the Squadron were present. At this meeting it was decided that the experiment of splicing the cable between the two ships should be made with the intention of commencing the operation from mid-ocean on the next trial. Having, after careful deliberation, arrived at this decision, Mr. Field started at once for England on one of the escorts, and on landing proceeded direct to London, where he informed the Directors of the company of the results of the expedition. Although it was now the middle of August, it was proposed to make another attempt in October, by which time, it was believed, an additional supply of cable, to replace what had been lost, could be manufactured. That month was said to be one of the mildest of the year, but it certainly did not sustain its reputation this time, for it proved to be one of the most boisterous and tempestuous that ever occurred on the Atlantic. It was fortunate, therefore, that the work was postponed till the summer of 1858, by which time there would be ample opportunity to devise and construct more perfect machinery, as the breaking of the cable on the 11th of August was partly attributed to the paying-out apparatus.

The Niagara having discharged her cargo in Plymouth, returned to New York, where she arrived on the 20th of November. The Agamemnon had also discharged her portion of the great sea-line, and the two ships were put out of commission until they should be required to resume the work. Mr. Field

had reached New York in September, having previously ordered the manufacture of about nine hundred additional miles of cable. As the distance between the two termini is, as stated, 1950 statute miles, the two ships were to be allowed 1500 miles each, which was regarded as a most liberal allowance to meet every possible contingency.

From October of 1857 till March of 1858 the public heard little of the great enterprise and settled down into the firm belief that it was not only impracticable, but that the men at the head of the undertaking were either visionaries, or were deceiving the stockholders, playing on the credulity of those who, in spite of the signal failures which had thus far attended every trial, might be induced to invest their money in what these keen and knowing skeptics did not hesitate to denounce as a gigantic bubble. Nor was this at all surprising, for there was a certain savant, who in the course of an abstruse and scientific lecture before a London audience, had proved that the thing could not be done; that it was beyond the attainment of human genius; in a word, that all the resources of science were unequal to the task. Nor was this all, for he had actually received a gold medal in testimony of the high appreciation in which his marvellous acumen and learning were held. It may be remembered that this particular scientist was preceded many years before by another learned and distinguished oracle of his day, a certain Dr. Dionysius Lardner, who wrote an elaborate disquisition to prove that it was impossible to propel a vessel by steam across the Atlantic for the all-sufficient reason that no vessel could be constructed to carry the necessary amount of coal required for the trip. Who thinks of the skeptics now?

The public, as stated, heard little or nothing of the enterprise from October of 1857 till March of 1858; but preparations were being made persistently and quietly for the resumption of the work during the month of June of the latter year.

Mr. Field accepted the office of General Manager at the urgent solicitation of the Board of Directors, and entered on the duties of his new office in January, 1858. Before leaving the United States for England, however, he applied to our Government for leave of absence for Mr. Wm. E. Everett, one of the most skillful and experienced officers of our Navy, and having

succeeded in the application, both gentlemen left New York on January 6th, 1858, in the Persia, for Liverpool, where they arrived on the 16th. Mr. Everett had been on the expedition of August, 1857, as the Chief Engineer of the Niagara, and while acting in that capacity had rendered very efficient service. But the task which he had now to perform was of a novel character, a task that demanded mechanical ingenuity and skill of the highest order. He was called on to devise and build a machine that would *surely* lay the cable, which machine, if successful, would save the company from disaster and bankruptcy. It is sufficient to say that he fully realized the responsible nature of the duty imposed upon him, and he entered on its performance with an assiduity equal to its importance.

In one of the dirtiest, dingiest and most out-of-the-way places of London called Gravel Lane, stood the factory in which this apparatus was to be made, and here, in this building, itself in strange harmony with the broken-down, ruinous aspect of the locality, Mr. Everett worked night and day in the construction of the machine that *did* lay the cable. At the end of three months he succeeded in the production of an apparatus that the best engineering talent in England agreed was the most perfect that could be made, a decision which was fully justified by its performance on the final expedition.

This machine consisted of four wheels with four grooves on each, each groove being four and a half inches deep. In these grooves the cable ran, and the speed of paying out was regulated by the action of brakes. The principal feature of the brakes was their automatic, self-releasing character, by means of which the pressure could be safely increased from one to two, or three thousand pounds. There was, in addition to this, another safe-guard, so that if the break accidentally failed to act, the strain on the cable might be immediately released. At the dynamometer, the indicator which told the amount of strain, stood a man holding the handles of a wheel similar to that used in steering ships; and the moment the indicator registered a heavier strain than the cable could safely stand, the pressure on the brakes was released by a few turns of the wheel, thus allowing the line to pass out more freely and with less risk.

Such, in brief, is a description of the Everett Paying-out

Machine, and it is not too much to say for its efficiency that it was an important, if not an indispensable factor in the successful accomplishment of the work of submerging the Atlantic Telegraph Cable, the precursor of the numerous lines that now unite Europe and America.

Two such machines were placed respectively on the Niagara and Agamemnon in the month of May, and by the end of that month the coiling of the cable on both ships was also completed. And that same coil was a wonderful thing in its way and the men engaged in the coiling were a wonderful band. They called themselves the "Cable Guard of the Niagara," and to the vigilance and skill with which they executed their part of the work the success of the expedition was in no small measure due. Stalwart, hardy, earnest workers, who, without a dollar in the enterprise, felt as much interest in it as if each man was the owner of a share of its stock. How faithfully and patiently they worked only those who saw them could tell. Coiling away foot after foot, yard after yard, mile after mile of the fifteen hundred miles of the tarred rope, they worked from morning till night and from night till morning on these huge bobbins, of which there were no less than seven on the three decks and hold of the vessel, packing away every fathom as neatly as a thread is wound upon a spool. From day to day and week to week they labored until the fifteen hundred miles had passed through their hands and each one of the cable circles was as full as it could hold. And while they worked they had their jokes, and their yarns of the oldest and the newest brand.

The 29th of May the Niagara and Agamemnon, accompanied by their escorts, the Gorgon and Valorous, started on a trial trip to the Bay of Biscay, where the splicing and submerging of the cable was tested and the paying-out machine was operated to the satisfaction and approval of the engineers. The squadron then returned to Plymouth, arriving at that port on the 3d of June. On the 10th of the same month they left Plymouth for the rendezvous in mid-ocean, where both vessels were to meet, splice the cable and start for the eastern and western termini of the Sub-marine Telegraph.

The weather was all that could be desired; the sun shone out from an almost cloudless sky, and the wind, which at times

sweeps with destructive violence along the rock-bound coasts of Cornwall and Devonshire, was subdued to a gentle zephyr. A numerous array of friends had assembled on the end of the Plymouth Breakwater, and under the shadow of its lighthouse, to bid us farewell. In a few hours the shades of evening had closed down on the scene and shut out from our view the last projecting landmark.

During the first three days the weather was no less favorable, but on the fourth an ominous change came over the face of the heavens; the bright skies had disappeared and large masses of threatening clouds obscured the sun. The violent gusts of a storm which was about to break upon us in all its fury, swept over the darkening surface of the ocean; the waves which but a few hours since were but as the ripples on a stream, were lashed into foam by the increasing force of the gale, and swelled into mountainous proportions. Everything that was necessary was done on board our ship in preparation for the coming storm; all sails were reefed, and the watchful supervision of our captain and officers saw that nothing was left undone for the security of our noble vessel and her costly freight, on the safety of which depended the realization of one of the grandest of human enterprises. The same precautions were taken on the Agamemnon, and the whole fleet kept on its course for the ocean rendezvous, seven hundred miles away. Every hour added to the violence of the storm; the squalls came up thicker and heavier and the huge waves surged and foamed about the ships in their fierce wrath. Still the Squadron held on its course, the unerring needle their only guide to that point where there was nothing but sea and sky.

For nine long and weary days they battled with one of the wildest storms that ever swept the stormiest of oceans. There was no cessation in the combined fury of wind and waves. The Niagara and Agamemnon kept company for several days, but the Gorgon and the Valorous had disappeared soon after the beginning of the gale. But the former also became separated, and had then to fight it out with the warring elements alone and unseen. Captain Preedy, the commander of the Agamemnon, was obliged to change his course because of what, as we presently learned, seriously endangered the safety of his ship. The immense coil which was placed in the hold,

and which contained over a thousand miles of the cable, had, in the rolling of the vessel, worked loose and into tangled masses until about one hundred miles of it were forced out of the circle and tossed about in the hold, burying beneath it all who had the temerity to approach. In addition to this serious situation it was feared that one of the deck coils would work loose also, and it was evident that under such circumstances, no human strength could save the Agamemnon. But the coil did not shift, and when on the eighth day the gale began to abate, the sky to clear and the waves to go down, there was many a glad heart on the British vessel. Only those who "go down to the sea in ships," and who have had such experiences, can appreciate the feelings with which they greeted the return of fair weather.

Worthy of the highest praise were the captains and officers of the Agamemnon for the coolness displayed under circumstances that might well appal the hearts of the bravest. Night and day they were on deck, and with an energy that was almost superhuman, they kept up the fight, inspiring their men with their own heroic courage, till they saved their ship from what seemed inevitable destruction.

Of the Niagara, which was the newer and in all respects the better ship, it can be truly said she bore her burden more lightly and passed through the storm almost unscathed. She had been constructed by her designer, George Steers, the celebrated builder of the Yacht America, which won the now historic race off Cowes over half a century ago and the prize cup that we have held ever since against all competitors.

The storm over, the reunited vessels set out with as little delay as possible for the rendezvous once more, though not for the last time, and reached the appointed place on the 25th of June. It was found impossible, however, to begin operations until the tangled coil on the Agamemnon was taken up and recoiled, which consumed a whole day in the operation.

On the 26th the work of splicing the two ends of the cable was done, the Niagara and Agamemnon being held together for the purpose by a hawser eight hundred feet long. As this was one of the most important details of the work, a somewhat detailed description is necessary to a proper understanding of the process. In the first place, the two ends were com-

pletely denuded of the outer wire, the hemp serving, and, finally, of the gutta percha, so that nothing was left but the copper core, or conductor, about six inches of which were exposed. The two ends thus prepared were laid together and secured by a binding of copper wire. This done, the second part of the process consisted of the soldering of the spliced wire, an additional binding and soldering following to reinforce the first binding. It was now ready to receive the gutta percha, which was laid on in a plastic state, to which it was brought by the flame of a blow-pipe in the hands of the operator, or splicer. The hempen strand, or serving, was next wound round the gutta percha, and over this was interlaced the outer wire. The spliced portion was still further strengthened by a wrapping of strong cord. This completed the operation; but as this portion of the line required still further protection it was relieved from all strain by two iron-bound loops which were placed one on each side of the splice and then drawn together in such manner as to leave the splice free from strain. A crescent-shaped piece of wood, about eight feet long, was next procured and the cable laid in a groove cut on the surface of the wood and secured in its place by a piece of flat iron of the same form and size as the wooden crescent.

At least two hours were passed in this operation and it was with a feeling of relief that we saw the splice with a heavy weight attached, descend slowly into the water, and the motion of the paying-out machine informed us that it was on its way to the submarine plateau two and a half miles down. A red flag was hoisted on the Agamemnon as the signal that she had commenced paying out, and soon after the cable was running over our stern at the rate of three miles an hour, both ships proceeding as slowly as possible to give the spliced portion time to reach the bottom. Hardly, however, had two and a half miles been paid out from our ship before the cable was torn apart, having slipped out of one of the grooves of the machine. It was, it seems, impossible to avoid the accident at the time, and it was, therefore, regarded as of slight importance, as it had not been caused by any deficiency in the working of the apparatus, and but little cable had been lost by the accident. So the ships returned once more, made another splice, and steamed away, each on its homeward course. But

they were again doomed to disappointment, for after forty more miles had been submerged from each of the cable ships an unaccountable break of the electrical continuity occurred, a break for which no satisfactory explanation could be offered. The electric current had ceased, and after holding on by the cable for several hours we were obliged once more to cut it and make for the rendezvous.

The 28th of June the Niagara and Agamemnon met again in mid-ocean; but inquiry among the electricians on either ship failed to elicit any information as to the cause of the interruption of the current.

This untoward incident caused the gravest apprehensions, as it was impossible to tell what agency might be at work at the bottom of the sea, an agency which we could not hope to contend against, because unseen. However, here we were preparing for still another trial. The splicing process was repeated for the third time and the ships started for their separate destinations. The work went on fairly well until each vessel had laid about one hundred and forty miles, when the cable again broke at the stern of the Agamemnon.

In accordance with the agreement made in anticipation of such contingency, the Niagara having gone over the stipulated distance of one hundred nautical miles, returned to Queenstown to coal, preparatory to starting on the third, and, as it proved, the final expedition. The Agamemnon, however, under the impression that we had not traversed the stated distance, returned to the rendezvous and waited there several days, when she, also, returned to Queenstown. The Niagara reached that port on the 5th of July, and the Agamemnon seven or eight days after.

Again we were obliged to carry the news of our defeat and to add another chapter to the disheartening story of repeated disasters. The intelligence reached London soon after our arrival at Queenstown, and the Directors were dismayed. Some did not hesitate to assert openly that the project was impracticable, declaring that it was better to sell what remained of the cable than to lose still more in what they insisted would be a fruitless attempt. They had, it was urged, tried it too often already, and what would the prudent, practical, common sense part of the world think? Think, of course,

what it never failed to say, with an emphatic and profane prefix, that it was "a bubble." The skeptical members of the company had, therefore, made up their minds that the cable should be sold. But Mr. Field insisted on still another trial, for having once entered upon the work, he was determined to prosecute it to the end. With his usual promptitude he once more set out for the British Capital, and on his arrival went at once to the Atlantic Telegraph Office. There he met the despondent members, into whom he infused new hope, spoke cheeringly of the certainty of success, alluded to the means they still had, and finally succeeded in persuading them not to abandon the enterprise until they had made one more trial. On the effect produced by Mr. Field's arguments upon the Board depended the resumption of the work. The majority of the members acceded to his appeal, and to the courageous and heroic effort which he then and there made the world is indebted for the triumph of the enterprise. But if he persuaded the majority of the Board, there was one unbeliever by whom it was so strongly opposed that he had his protest entered on the minutes of the meeting against any further trial, on the ground that it was sheer madness. His protest was placed upon the record and there it still stands over his own signature.

Mr. Field returned for the last time, as it proved, to Queenstown. July 17th the Niagara was again once more on her way to that ocean rendezvous to which they were ever returning. The Agamemnon did not leave till the following morning; but the Gorgon and the Valorous sailed before our ship.

The evening of our departure was sombre and threatening, and the dark clouds with which the heavens were overcast looked like a huge funeral pall. The aspect of the elements was certainly inauspicious, but the die was cast, and, as the result proved, fortune at last smiled upon the enterprise. The paying-out machine had, on trial, answered the highest expectations; no fault could be found in it, thanks to the skill and ingenuity of Mr. Wm. E. Everett. There still remained on the two ships about twenty-five hundred miles of cable and that allowed a fair surplus over the actual distance.

Our passage to the rendezvous was marked by such weather as is rarely if ever seen in those high northern latitudes, with the air so still for many days that it seemed as if our ship was

in the region of perpetual calms, and that the sea on whose mountainous waves we had been tossed for eight long and anxious days, had become as still as the telegraph plateau itself. Here we are, six days out, and at our appointed place, half-way between the two island outposts of America and Europe; here where there is no trace of man's work; here where no voice breaks the silence of the solitude save the harsh cry of the sea-birds. Five long and anxious days we waited for the Agamemnon; the Valorous and the Gorgon had already arrived. At last she made her appearance on the morning of the 20th of July. She had sailed a great part of the way to save coal, of which she had but three hundred tons, while of the cable there were thirteen hundred miles for the half of the distance to be traversed. The Niagara had five hundred tons of coal and about the same length of cable.

It was one o'clock when the process of splicing, already described, was completed and the signal was given to pay out the line. The wheels of the machine commenced revolving at the rate of five miles an hour and the weighted splice was soon rapidly sinking to its bed of ooze on the plateau. An hour has passed since it was lowered over the stern of the Agamemnon, and the ships are now at least five miles apart. Three o'clock has just struck and two hours have passed since we parted company; the Agamemnon is on the very verge of the horizon, and in another hour we shall be alone on the ocean with our faithful guide, the Gorgon, leading the way to the land of fogs.

Next to the paying-out machine, one of the most interesting objects connected with the work is the circle from which the cable is now descending to the depths at a speed of from six to seven miles an hour, a speed which will be increased as the vessel approaches nearer her destination. As the line is uncoiled, flake after flake, it is conducted to the paying-out machine over a series of pulleys from which it is delivered into the grooved wheels and passes on till it reaches the single wheel over the stern as it leaves the vessel. In the particular circle from which the cable is being unwound about a dozen of the most experienced coilers are stationed at regular intervals, charged with the vitally important duty of looking out for kinks, and when the last turn of each flake, or layer, is reached,

to take the bight, or bend, and lead it in safety to the cone which stands in the center of the circle. As this is the critical moment the utmost caution and vigilance is necessary, and as each flake is liable to kink when the short turns are approached, the danger attending the operation will be realized when it is known that it must be performed several hundred times on board both ships before they arrive at their respective destinations.

The next and no less important point of interest, where we obtain all the news in regard to the electrical condition of the cable, or the continuity, is the office of the electricians. To get there we have to descend to the main deck and pass on till we come to the so-called Ward Room Coil, at one side of which a small apartment had been fitted up for the electrical apparatus. It is barely large enough to accommodate half a dozen persons comfortably; but space is precious on both ships and it is economized to a miserly extent. The electrician is taking note of the signals which are passing along the whole length of the cable on board the two ships. Here are the batteries that generate the subtle current, the commutator, the electro-magnetomotor, the marine galvanometer and a number of other instruments with titles of "learned length and thundering sound." Discarding details, it is gratifying to be assured by the chief electrician, Mr. de Sauty, that the continuity is all right, and with a fervent hope that it will remain in that happy state to the termination of the voyage, we leave the little office.

Six hours have passed since the splice was made on the rendezvous and over sixty miles of cable have been submerged by both ships. It is past seven o'clock and all is going on well; but the old adage says "appearances are deceitful," and in this instance it is painfully verified, for although the paying-out continues without interruption, and the machine is doing its part of the work in splendid style, we hear with renewed feelings of dismay and despondency, that the continuity is becoming weaker every minute, and that if there be no change soon for the better, the electric current will have ceased altogether. But just as we are about to yield to despair, the glad news is announced that although two hours have elapsed since the first unfavorable indications were observed, it not only holds on,

but that it is improving every moment and in less than five minutes the joyful tidings reach every part of the Niagara that the current is coursing through the twenty-six hundred miles of cable with unabated force.

All through the night of the 29th of July the machine was in motion and the cable left the stern wheel at the rate of five and six miles an hour. And so it continued till the 1st of August, three days since the splice was lowered. The weather, which might be truly called ideal for cable laying, began to change, and although the barometer had risen to a prominent altitude, there were, according to the weather-wise, unmistakeable indications of a gale. The wind increased hourly, until it attained the magnitude of a stiff breeze; but we had no gale, and although a heavy rolling sea had set in from the northwest, it gradually became evident that there would be no storm. But the Niagara never rolled and plunged during the whole voyage as in this sea, and our fears were again aroused for the safety of the cable. To this new alarm was added still another: the old spectre of a weak and defective current haunted the harassed, unnerved and weary watchers, from the Captain's cabin all the way down to the forecastle. During three long hours this dread anxiety held possession of all on board until human endurance seemed to have reached its limit, when the suspense was at last broken by the cheering report from the electricians' office that the wavering continuity had returned in full strength and volume.

This was the last alarm, and from now on our confidence increased as the work progressed to the end. Signals continued without further interruption from ship to ship, which were now eight hundred miles apart, and these conveyed the intensely gratifying assurance that while the Agamemnon had her own troubles, she had shared our good fortune in overcoming all difficulties, and was jubilant over her success.

Three days more brought us in sight of land, and words fail to express the feelings with which we gazed on that rock-bound coast as we approached the entrance to Trinity Bay, at the terminus of which the cable was to be landed the following day, the ever-memorable 5th of August, the eighth day since we started from the rendezvous. But, as we draw nearer to our terminus and at last enter between the headlands of

Trinity Bay, a strange scene of enchantment greets our astonished sight. This land of wonders cannot surely be the barren island for which we have so earnestly longed during our anxious passage! What shore could it be that lay there in the glowing light, beautiful as an enchanted land and changeable as the figures in a keleidoscope? Now it presents the rugged aspect and bleak outline which marks nearly the whole coast range of Newfoundland, with Alpine summits that for a great portion of the year are covered with snow, or veiled in impenetrable fogs. And now it presents the form of an immense table land, level as the great western prairies. But, under the potent spell of the mirage, (for this is the necromancer whose magic power has wrought these atmospheric marvels,) scenes of bewildering variety succeed each other in rapid succession. Icebergs of all forms are around us, some white as the unstained snow; others green and translucent, sparkling in the sunlight, and as we gaze, others of gigantic proportions fall asunder, sink beneath the surface, but only to rise again in new and fantastic forms.

We are now passing up Trinity Bay, and as the shades of evening settle down upon the ocean, the mirage and all its scenes of enchantment disappear, leaving only the great headlands visible. Eighteen miles further is the landing place of the cable, the temporary Atlantic Telegraph Station on the American side as Valentia Bay is on the European side.

The steamer Porcupine, which had been dispatched from England under the command of Captain Otter, to await our arrival, now appeared in sight, and prepared to lead the way to the Bay of Bulls, where the cable was to be taken ashore the following day. Mr. Field, however, concluded not to wait and started in a small boat for the Telegraph Station, where he arrived some six or seven hours after. The occupants of the house were all asleep, but when they heard that the cable was laid they were literally bewildered. By one of these same electricians the first message was wired to nearest station connecting with St. John's, from which it was forwarded to the United States, where it was received with a welcome that came from the great heart of the nation.

At six o'clock on the historic 5th of August, 1858, a procession of six boats started from the Niagara which lay about

half a mile from the landing. The last boat in the line contained sufficient cable to reach the station. As we left the ship the men in the last boat paid out the line with their hands, an operation which was performed in less than twenty minutes; and, as the procession landed, Mr. James North, the First Lieutenant of the Niagara, presented, in due form, the end of the first ocean cable to his superior, Captain Hudson. Another procession was now formed, Captain Dayman, of the Gorgon, and Captain Otter, of the Porcupine, leading the way, holding the tarred cable in their hands, and followed by the officers of the three ships in regular procession, in accordance with their respective ranks. The cable hands of the Niagara, with a portion of the rest of the crew, formed the rear of this memorable procession. Plodding through bog and over rock, the pioneers, who had the glory of landing the first submarine line, came in sight of the Telegraph Station, where in less than half an hour the conductor was put in connection with the electrical apparatus, *and the telegraphic union of the two worlds was consummated.*

Such a consummation could not be permitted to pass without due and appropriate recognition and ceremonies. Accordingly, Captain Hudson, as the ranking officer, after an admirable address, inspired by the solemnity of the occasion, pronounced in reverential tones, that touched the hearts of his audience, a prayer of thanksgiving to Providence for the success of the great enterprise.

From Trinity Bay the Niagara set sail for St. John's, where her arrival was made the occasion of a series of popular ovations and demonstrations, including official addresses of welcome, a public dinner, and a ball in the Government Building, winding up with a regetta on Lake Quidi Vidi.

The 18th of August, after unavoidable delays, from the constant recurrence of fogs during the passage, saw the Niagara entering New York's incomparable bay, and we were home at last amid rejoicing and welcoming friends.

What though the cable had ceased to work four weeks after its submersion; the great problem had been solved and the way had been so clearly, so brightly blazoned as to make the future so safe, so prolific in results, that to-day, forty-eight years after the landing of the first submarine cable in Newfoundland, the

aggregate length of submerged lines throughout the world is, according to reliable statistics, no less than TWO HUNDRED AND TWENTY-FOUR THOUSAND SEVEN HUNDRED AND SIXTY-SEVEN MILES.

No. 223 E. 49th Street, New York, November 2nd, 1906.

MINERAL PRODUCTION OF THE UNITED STATES BY STATES.

A new feature of the 1905 number of the volume, "Mineral Resources of the United States," brought out annually by the United States Geological Survey, is a series of tables, compiled by William Taylor Thom, which shows the value by States of the mineral products of the country.

These products, so listed, include both certain raw materials and also certain derivative materials in their first marketable condition, which do not appear in the table of mineral products of the United States as a whole. For example, both pig iron and iron ores are excluded as important products entering into the commerce of certain States, and in like manner are included both pig lead and lead paints; both clay products and raw clay; both coal and its immediate derivatives, coke, gas, illuminating gas, ammonium sulphate, and coal tar; bauxite and aluminum; and also alum and aluminum sulphate. These derivatives and raw materials are here given, regardless of the consequent duplication of values, in response to a constant demand for this information thus arranged by States.

Study of these tables will afford most people more than one surprise. For example, we think of Colorado and California as our most representative mineral States, and yet, the actual value of Illinois' mineral products was far greater than that of either California or Colorado last year; more than double, in fact, the value of California's output, for although Illinois has neither silver nor gold it produces great quantities of cement, clay, coal, pig iron, stone, and zinc, which are worth much silver and gold in the world's markets.

The sums total of these State outputs for the year run as follows:

Alabama	$53,585,288	Montana	65,501,049
Alaska	16,483,759	Nebraska	1,357,846
Arizona	41,346,134	Nevada	9,873,385
Arkansas	4,470,784	New Hampshire	2,028,638
California	43,406,258	New Jersey	31,818,121
Colorado	59,280,944	New Mexico	4,382,114
Connecticut	4,098,625	New York	65,056,287
Delaware	762,944	North Carolina	2,486,063
District of Columbia	317,021	North Dakota	665,480
Florida	4,828,783	Ohio	169,203,710
Georgia	6,300,654	Oklahoma	623,333
Idaho	16,768,855	Oregon	2,441,973
Illinois	105,065,567	Pennsylvania	569,828,673
Indiana	41,781,678	Rhode Island	1,327,795

Indian Territory	5,763,346	South Carolina	2,494,457
Iowa	16,098,028	South Dakota	7,571,573
Kansas	37,971,198	Tennessee	19,641,528
Kentucky	14,871,811	Texas	13,752,346
Louisiana	6,815,430	Utah	28,447,799
Maine	5,065,804	Vermont	8,797,834
Maryland	20,048,257	Virginia	21,751,986
Massachusetts	14,024,200	Washington	8,790,544
Michigan	81,760,141	West Virginia	74,731,376
Minnesota	41,305,375	Wisconsin	16,804,611
Mississippi	874,279	Wyoming	8,657,202
Missouri	23,035,899		

The chapter of "Mineral Resources," entitled "Summary of the Mineral Production of the United States in 1905," is issued separately, in pamphlet form. Those desirous of knowing the details of State production should make request for this summary from the Director of the United States Geological Survey, Washington, D. C.

THE MINERAL PRODUCTION OF THE UNITED STATES IN 1905.

A most interesting chapter in the volume entitled "Mineral Resources of the United States, 1905," published by the United States Geological Survey, is that which contains the summary of the mineral production of the United States during that year.

In 1905, for the seventh time, the total value of our mineral production exceeded the enormous sum of $1,000,000,000. The exact figures for 1905 are $1,623,877,127, as compared with $1,360,883,554 in 1904.

As heretofore, iron and coal are the most important of our mineral products. The value of the iron in 1905 was $382,450,000; the value of the coal, $476,756,963. The fuels increased from $584,043,236 in 1904 to $602,477,217 in 1905, a gain of $18,433,981, or 3.16 per cent. Anthracite coal showed an increase in value of $2,904,980 from $138,974,020 in 1904 to $141,879,000 in 1905. The increase in value of the bituminous coal output over 1904 was $29,480,962, a combined increase in value of $32,385,941 in 1905, or 7.3 per cent.

The gain of $262,993,573 in the total value of our mineral production is due to gains in both metallic and non-metallic products, the metallic products showing an increase from $501,099,950 in 1904 to $702,453,108 in 1905, a gain of $201,353,158, and the non-metallic products showing an increase from $859,383,604 in 1904 to $921,024,019 in 1905, a gain of $61,640,415. To these products should be added estimated unspecified products, including molybdenum, bismuth, tungsten, and other mineral products, valued at $400,000, making the total mineral production for 1905 of $1,623,877,127.

Besides the usual table and summary of quantities and values of the country's mineral output by products, the volume contains this year, for the first time, a summary, in tabulated form, of the value of the mineral products by States. These tables were compiled by Mr. William Taylor Thom.

(Read by title at the Stated Meeting held Thursday, January 24, 1907.)

Electrical and Chemical Energy.*

By Gustaf M. Westman.

Before going into the subject we will make a comparison between the kinetic energy of gases and electrical energy.

Our formula for the kinetic energy of gases is $4\left(n^{\frac{k-1}{2k}} - 1\right)^2 \times \frac{C_v}{2} \times 546$, in which n is the range of pressure in atmospheres per square meter, and 546 the unit of energy in kilogram calories.

We must remember that this equation represents the centrifugal force of the ether molecule or corpuscle of the gas because the molecule itself does not take any part in the work performed.

Joule's formula for the electrical energy is $0.24\ C^2 \times R$ gram calories per second, and must be multiplied by 1000 in order to be in accord with our formula for the kinetic energy of gases. Besides we change the amperes into coulombs, whereby the time goes out of equation. For the same work performed the two equations will be equal, and consequently $4\left(n^{\frac{k-1}{2k}} - 1\right)^2 \times 546 = 240 \times \text{coulombs}^2 \times \text{resistance}$.

We shall show later that if the resistance is chosen 2.23 the square of the centrifugal force will be equal to the square of coulombs, which explains the current as an act of the centrifugal forces of the corpuscles.

In order to create electricity it is necessary that two forces in opposite directions act on the same molecule, whereby the centrifugal force of the corpuscles in the molecule are liberated and communicated to the corpuscles in the conductor.

*Read by title.

We assume at the outset that by relieving the pressure, the corpuscles are put in rotation, which is the reverse of the molecule itself being put in rotation by pressure applied to it.

In certain galvanic cells on account of maximum of work to be performed, the metal in the electrolyte is replaced by another metal in such way that the negative radical of the electrolyte is attracted from the positive pole until the new combination is formed.

When the first metal in this way is relieved from the pressure of the negative radical, the centrifugal force of its corpuscles puts them in rapid rotation, which is communicated to the conductor between the poles when the metal is precipitated on the negative poles. The reaction between the corpuscles of the precipitated metal and the conductor constitute the current.

The same current is likewise produced by a dynamo, where the corpuscles of the surrounding gas molecules are put in rotation by closing and opening a magnetic communication, and their rotatory force communicated to the circuit.

By the attraction of the clouds towards each other, and by condensing water molecules in the clouds to water, two opposite forces work on the same molecule, whereby the centrifugal force of the corpuscles is liberated and discharged by meeting the attractive force of the earth. This produces an arc of lightning.

Flames and explosions are considered as chemical actions, notwithstanding they cannot be explained as such, because they are, in fact, electrical discharges like lightning, from which they differ in the liberation of the centrifugal force, which is here brought about through chemical attraction or pressure.

An explosion is always sudden, and it is not likely that all parts can be brought into contact in a moment, at least if they are in solid state, as in the case of gunpowder.

Many explosives are not ignited by heat, but by concussion, which shows undoubtedly that pressure liberates the centrifugal force.

The same reasoning, but in less visible degree, applies to flames.

Having shown how the electric current is generated in an electric battery and dynamo, and how the electric current is

generated and discharged in lightning, in flames, in explosives, and that the centrifugal force is liberated in all cases, we will now see when a current makes the centrifugal force visible in the corpuscles.

By subjecting minerals containing various metals to the spark of a high tension induction coil, characteristic colors are imparted to the spark by the different metals.

It is not the heat that produces these colors, but the centrifugal force, which like radio-active matter puts the corpuscles of the molecule in motion.

By association (combination) of matter, which produces pressure, the centrifugal force is always liberated and produces an arc, as can be seen in flames, if the heat is sufficient to cause the same.

By the dissociation (or the reverse of combination) accomplished by heat, one of the constituent parts must acquire centrifugal force in order to be released from its combination so as to enter into another combination.

As association or dissociation depend on the centrifugal force, the energy liberated or absorbed is a measure of it in all chemical actions.

The photograph, which depends upon dissociation by chemical action; the phonograph, which depends on mechanical action; the wireless telegraph, which depends upon magnetic action; the telephone, microphone, etc., which depend upon electrical actions, are all due to the centrifugal force, either liberated or absorbed.

In all this we consider the electric current nothing but a flow of the centrifugal force of the corpuscles, which produces the same effect as the pressure of gases.

When gases are compressed the centrifugal force is stored and reveals itself in pressure.

We measure the pressure in a straight line, notwithstanding the motion is in circles, as already has been shown in our theory for the kinetic energy of gases. It is, therefore, not different in that respect from the electric current.

Equilibrium between the attractive and centrifugal forces exist only when the molecules are not acted upon by other molecules, or affected by pressure which puts the centrifugal force in action.

When molecules expand, no matter how the centrifugal force is introduced, heat is absorbed, and when they contract centrifugal force is liberated, whereby heat is created.

The electricity is created by pressure; it moves in circles; it can produce work, and the formula for the work is identical with the formula of the kinetic energy of gases, which is produced by attraction and moves in circles. When the kinetic energy is based on the centrifugal force, how can it be otherwise than that the electricity is based on the same?

That the heat produced by a combination is just the same as liberated centrifugal force by its effort to be discharged against the ever present attractive force as resistance, seems to us to indicate that in chemical action the electricity plays such an essential part, that one cannot say where the chemical action ends and the electrical action begins. The attraction is always of electrical nature.

All molecules have a molecular volume, which depends on the centrifugal force, and is changed by combination with other elements in consequence of pressure of affinity. This affinity is in direct proportion to the electrical potential, which, therefore, must depend on the centrifugal force.

It seems to us that too little attention has been given to the centrifugal force, which plays the most important part in all phenomena coming before us, not only in matter itself but in the form it takes, either as sound, light, heat, power or electricity.

We therefore consider the electric current as an action of the centrifugal force, which puts the corpuscles of the molecule into rotation, and produces the same effect as the stored centrifugal force of gases, when either discharged or subjected to their respective resistance.

After having shown a comparison between the kinetic energy of gases and the electric current, we will go a step further and show the relation between chemical and electrical energy.

As can be understood from our theory of the electrical current, the heat evolved by chemical reaction and the heat evolved when the electrical current is discharged, rest on the same principle, namely, the attractive force or pressure. The difference is that in the electrical current the centrifugal force origi-

nates in the corpuscles and heat is produced, when the current meets attractive force or resistance, but that heat is produced directly in chemical reactions. The attraction between two bodies, which acts like pressure, causes a rotatory movement in turn, which rotatory energy puts the corpuscles in the conductor in motion, but in a chemical action causes friction and consequently heat, which stops when both parts are alike in size, when they combine with each other.

In chemical and electrical processes the heat or the current, which produces heat, when discharged, is consequently a reaction from two bodies, and it cannot be estimated how much heat is produced from each. That is shown perfectly in the many tables of substitution of one element for another by Berthelot. Alkaline and earthy molecules are exceptions, which show an even heat-difference between them when one is substituted for another.

Fl^2, Cl^2, Br^2, I^2, Cy^2 in aqueous solution when displaced one for another in combination with an alkaline or earthy molecule shows a certain difference, likewise for O, S, and Se in aqueous solution. The heat evolved in combination of the same negative elements with all other molecules does not give anything like a constant heat-difference by substitution between themselves, or by substitution of the negative radical—one for the other.

The only thing that can be estimated is the alteration of the size of each part, from which a conclusion can be drawn about the work performed by each of them.

We will first show how this can be done in chemical reactions.

Our principal energy formula for solid and liquid bodies is

$$n^{\frac{2(k-1)}{k}}\left(n^{\frac{k-1}{k}}-1\right)\frac{c_v}{2}\times 546$$

in which n is the range of pressure in atmospheres per square meter, and equal to the product of the number of molecules per cubic meter multiplied by 22.3, thus showing how many times the molecule has been contracted in changing from its gaseous state to its liquid state at the boiling point.

If m is the number of molecules per cubic meter at boiling

point $\frac{1}{m}$ cubic meter is the volume of that molecule, and if $\frac{1}{m^2}$ square meter is the base, the molecule contains m equal layers, which we call points of that element.

The kinetic energy of gases shows itself to be inversely proportional to its heat capacity divided by 2 and as the energy of matter is directly proportional to the unit of energy the relative energy of all matter can be expressed by $\frac{2 \times 546}{c_v}$. Cal.

Heat is the reaction from converting attractive force into centrifugal force or converting linear motion into rotatory.

This can best be seen by the process of compressing gases when the attractive force is used for compression, and the centrifugal force is stored in the gases. For all chemical reactions the pressure, which causes the contraction, creates a centrifugal force, whereby heat is developed.

The heat capacity is the quantity of heat in calorics evolved per degree of temperature, which for the above formula must be at the boiling point.

Notwithstanding that the alkaline elements and the halogens contract to less than half, and that many elements contract only a few points and others not at all, we understand the energy of an element to be equal to the heat evolved when its size is reduced to one-half at its boiling point.

The more energy an element has when reduced to half its volume, the smaller is the heat capacity. On that account, and on account that log $c_v^{\frac{k \times 1}{k}}$ is constant we assume that the product of the energy and the heat capacity at the boiling point is the same for all elements. This assumption is not substantiated by experiments, as no such determination was ever made except for Hg.

The energy of Hg^2 is 87,200 Cal., and the heat capacity at the boiling point for $Hg^2 = 12.5$.

$87{,}200 \times 12.5 = Q. \times c_v$; if Q is the energy of the element in question and c is its heat capacity at boiling point. From the energies of elements is calculated the heat capacities as follows:*

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*We refer to our thermochemical data for the energies of elements.

$H^2 = 1.6$, $K^2 = 16.4$, $Na^2 = 16.4$, $Si^2 = 16.4$, $B^2 = 2.4$, $O^2 = 3.2$, $F^2 = 4.8$, $S^2 = 8.6$, $Ca = 13.3$, $Sr = 6.8$, $Ba = 6.8$, $Mg = 6.5$, $Zn = 6.5$, $Cd = 10.4$, $Hg^2 = 12.5$, $Ag^2 = 6, 8$; $C = 4.2$, $Si = 11.2$, $Al^2 = 8.7$, $Cu^2 = 10.4$, $Ni = 2.64$; $Co = 2.64$, $Fe = 6.25$, $Sn = 5.6$, $Mn = 5.5$, $Pb = 6.28$; $Au^2 = 8.5$; $N^2 = 3.2$; $O^2 = 8.5$, $As^2 = 10$, $Sb^2 = 11.8$; $Br^2 = 10.4p^2$ $Cl^2 = 8.8$; $Br^2 = 13.2$; $I^2 = 17.6$.

If we except the heat capacity for alkaline matter and the halogens, which, on account of their greater contraction. must not be counted, the most remarkable fact of the above table is that the heat capacity of H^2 decreases from 4.8 at ordinary temperature to 1.6 at the boiling point, or to one-third, and that the heat capacity of C increases three times from 1.38 to 4.2.

The heat capacity of O^2, N^2, P^2 decreases ^{2} and that of Ag^2 Co, Ni, Ag, $\frac{1}{2}$, while the heat capacity of Si and Ca is increased by 2, and of Cd by $1\frac{1}{2}$.

The heat capacity for the rest of the elements is about the same as at ordinary temperature, a remarkable fact for which no explanation can be given.

The volumes at the boiling point for the following elements have been found directly from the specific gravities in liquid conditions, namely, for $O^2 = 34.3$, $N^2 = 33$, $Cl^2 = 23$, $Br^2 = 18.5$, which figures are ordinarily placed at the foot of the symbol.

In many cases the number of molecules per cubic meter in the solid state is to the number of molecules per cubic meter at the boiling point as the square root of the boiling point is to the square root of the freezing point.

If the ratio of the square root of the boiling point to that of the freezing point is made the divisor of the number of molecules per cubic meter in the solid state, we will have the number of molecules per cubic meter at the boiling point.

$$K = \frac{22.5}{1.62} = 14, \quad Na = \frac{42.5}{1.65} = 27, \quad Hg = \frac{69}{1.61} = 43.6,$$

$$Zn = \frac{108}{1.29} = 84, \quad S = \frac{64}{1.26} = 51, \quad P = \frac{64}{1.34} = 48, \quad Al = \frac{96}{1.31} = 70.$$

In Cd the solid volume is to the volume at boiling point di-

rectly as the boiling point is to the freezing point, namely, Cal$=\frac{76.8}{1.78}=44$.

For the other elements "m" has been found from the energy evolved in combination with 4 to 5 separate elements, when "m" and its energy are known. If we deduct from the energy evolved by such combination the energy belonging to the known element, the remainder must belong to the unknown element with the same volume number as the known element. If we perform the same operation with four or five other known elements, we have a certain volume number for each reaction, and an energy corresponding to that volume number. From all these volume numbers and corresponding energies, we can find the zero volume number for the unknown element.

When the energy of each element is to be determined from the heat evolved by combination, the volume-number plays the most important role. A negative element enters into the combination, not only with one, but with two, three, sometimes four atoms, and must under the same volume-number commence its action in combining with the whole series of positive elements, each of different size and energy. It is easily understood that only a small difference in the volume-number would be fatal for all calculations. It is therefore necessary to see the volume-number from as many sides as possible.

We mark the number of molecules per cubic meter at the bottom of each symbol and place them in the eight groups of the periodical law, with two series for each group. In this way it can be seen how the volume-number alters from one to another in this same group, and it is reasonable to believe that the periodical law has a great bearing on the sizes of the atoms, just as it has on the weights.

1.	H^2	Li^2	K^2	Na^2	Cu^2	Ag^2	
	78	28	7	13.5	40.5	40	
2.	Ca	Sr	Ba	Mg	Zn	Cd	Hg
	41	38	32	84	84	44	43.6
3.	B^2			Al^2			
	45			35			

4.	C 72	Si 36	Sn 54	Pb 48.5	
5.	N^2 33	P^2 24	As^2 23	Sb^2 23	Bi^2 23
6.	O 34.3	S 51	Se 49		
7.	F^2 57	Cl^2 23	Br^2 18	I^2 13	

8.	Ni 88	Fe 101	Co 108	Mn 115

In the first group the number of molecules per cubic meter of K^2, Na^2, Li^2 stands nearly as 1. : 2 : 4, and are nearly equal at Cu^2 and Ag^2.

In the second group Cd, Ca, Sr and Ba have a difference of 3 to 6, also Zn and Mg, and Hg differs from Cd only 0.4. The difference in C, Sn and Si is 18.

The second series of the fifth group are nearly equal.

In the sixth group $O^2 : S = 1\frac{1}{2}$.

Seventh group differs by 5.

Eighth group has a difference of 7, except that the difference between Ni and Fe is 13.

Most elements contract considerably by combination, but C contracts only 6. and H^2 only 3.14, and Mn, Fe, Co, Ni and B^2 do not contract but expand.

Inserting the values of "m" and c_v in the formula $\frac{2 \times 546}{c_v \times m}$ the following relative heat quantities are obtained per unit: $O^2 = 10$, $N^2 = 10.5$, $Cl^2 = 5.4$, $Br^2 = 4.6$, $I^2 = 4.8$, $S^2 = 5$, $K^2 = 9.6$, $Na^2 = .5$, $Li^2 = 2.4$, $Ba = 5$, $Sr = 4$, $Ca = 2$, $Mg = 1$, $Zn = 2$, $Cd = 2.4$. $Hg^2 = 2$, $Ag^2 = 4$, $Cu^2 = 2.6$, $Al^2 = 3.6$, $B^2 = 7$, $Mn = 1.73$, $Fe = 1.72$, $Co = 3.8$, $Ni = 4.7$, $Sn = 3.6$, $Pb = 3.6$, $Si = 2.7$, $C = 3.6$, $P^2 = 5.4$, $As^2 = 4.8$, $Sb^2 = 4$. $Bi = 4.55$ $H^2 = 8.8$, $F^2 = 4$, $Au^2 = 3.4$.

The number of atoms is twice that of the molecule. When the atoms of a molecule act against one another, the energy of

each atom is one-fourth of the energy of the molecule, but only half as much when the atoms do not act against one another.

We estimate the energy per volume-number as follows: $O = 2.5$, $N = 2.6$, $Cl = 1.35$, $Br = 1.15$, $I = 1.20$, $Cu = 0.65$, $F = 1.35$, $H = 2.2$, and for $S = 2.5$, $As = 2$, $Hg = 1$.

When these figures are multiplied by "m" the element is brought to half of its size and evolves as much heat as corresponds to "m" $\times$ heat evolved per volume-number.

After an element is combined, the compound has a heat capacity nearly equal to both its constituents, and we intend to show that $\frac{1092}{C_v \times m}$ is the energy per volume-number for the compound, if Cv is the heat capacity at boiling point and "m" the number of molecules per cubic meter.

H^2O; $\frac{19.3 \times 28 \times \frac{1}{2}}{1092} = 1$ Cal. Na^2O; $\frac{1092}{19.2 \times 45} = 1.25$ Cal.

Bn O; $\frac{1092}{13.5 \times 31} = 2.6$ Cal. Sr O; $\frac{1092}{11.9 \times 46} = 2$ Cal.

Ca O; $\frac{1092}{13.8 \times 58} = 1.36$ Cal. Mg O; $\frac{1092}{11.4 \times 80.5} = 1.19$ Cal.

Cu O; $\frac{1092}{13.6 \times 80} = 1$ Cal. Pb O; $\frac{1092}{11.4 \times 40.8} = 2.2$ Cal.

So^3; $\frac{1092}{10.8 \times 23} = 4.4$ Cal.

The energies per volume-number are confirmed in the determination of oxides.

If we now go to the chlorides and sulphates, we must observe that both the components act as independent bodies against each other, and therefore the equation must be changed into $\frac{.546}{C_v \times m}$.

All the energies of the following compounds are derived from their combination with H^2O.

Sr Cl^2 $\frac{546}{17.4 \times 19.3} = 1.6$ Cal.; Ca Cl^2 $\frac{546}{20.5 \times 20} = 1.33$ Cal.

$Mn\,Cl^2 \; \frac{546}{19.7 \times 19.7} = 1.41$ " ; $Fe^{II}\,Cl^2 \; \frac{546}{21.6 \times 20} = 1.26$ "

$Sn\,Cl^2 \; \frac{546}{23 \times 14.6} = 1.44$ " ; $Mn\,O^4S \; \frac{546}{23 \times 18.2} = 1.27$ "

$Zn\,O^4S \; \frac{546}{25 \times 20.5} = 1.05$ " ; $Cd\,O^4S \; \frac{546}{26 \times 22.7} = 0.9$ "

Modern electric theory states that every element contains 1000 corpuscles or electrons, which view is substantiated by Faraday's law, and if we multiply the figures given above with 1000 we arrive at the exact heat quantities.

There is, however, a difference between chemical and electrical energy, in that the former originates from the molecules or atoms, while the latter depends on the corpuscles therein.

The energy for each electron is therefore 546 Cal. divided by $\frac{C_v}{2}$ and as the current divides into two parts, one part is equal to the square root of 546, and the other the square root of 546 divided by $\frac{C_v}{2}$. To arrive at the energy for a molecule, one of the forces must be multiplied by 1000. The square root of 546 is 23.366, and if we multiply the force by 1000 it will correspond to 23,366 Cal., which figure will replace one volt of the electric current in separating one chemical equivalent from its combination.

It has been found by many experiments that 0.001118 grammes of silver are separated from its combination with a current of one coulomb, and as the chemical equivalent of silver contains 108 grammes, it will take $\frac{108}{0.001118} =$ coulombs to eleminate one univalent equivalent. Instead of gramme molecule we can use kilogram molecule, if the calories are made in kilogram calories.

Joule's formula can be written 0.24 volts $\times$ coulombs, and as Ag Cl develops 29,500 Cal. in formation $\frac{29500}{0.24 \times 96.540} = 1.27$ volts are necessary to attract the constituents to the poles,

which confirms our statement, that one volt can be replaced by 23,366 Cal.

Formerly we made a comparison between the kinetic energy of gases and the current, and will now compare the current with the energy in matter, or with our principal energy formula

$$n^{\frac{2(k-1)}{k}}\left(n^{\frac{k-1}{k}}-1\right) \times \frac{c_v}{2} \times 546,$$

in order to show how the electrical forces stand to the natural forces.

We must select for that purpose a salt, for instance Na Cl, which has a resistance against the attractive force from the poles equal to 4.16.

If this is performed Joule's formula will be written $\frac{\text{volt x coulomb}}{\text{resistance of salt}}$ gram calories or $\frac{\text{volt x coulomb x 1000}}{\text{resistance of salt}}$ kilogram calories, in order to be in accord with our principal formula.

The resistance of the salt is $\frac{23.3 \times 2}{c_v}$, and as both formulas equalize each other when the same amount of work is performed, we have $\frac{\text{volt x coulomb x 1000 x } \frac{c_v}{2}}{23.3}$ = centrifugal force, x attractive force, x $\frac{c_v}{2}$ 546.

From this it can be seen that $\frac{\text{volt x coulombs}}{\text{centrifugal forces x attract force}}$ = 12.7.

This is very significant, because 12.7 equals 4, π which is a factor in all problems of rotatory energy, showing that the work performed is a rotatory one, and besides that the work cannot be performed by the forces belonging to the molecule. The forces must, therefore, belong to the corpuscles, which in some way have been liberated to act, and it shows undoubtedly that the current originates from the centrifugal force of the corpuscles.

After having seen how the chemical energy can be converted into electrical energy, the most important question is to find how the current is conducted, and we will first state our opinion in regard to metallic conductors.

To understand the conductivity of the current, we must go to

Joule's formula for the heat evolved by its passage through the wires. As that formula is identical with our formula for the kinetic energy of gases, we suppose that the same deductions can be drawn in both cases. We have shown that when a gas is discharged from pressure into a vacuum, the motion of the molecule is a circle.

On these premises, and because the centrifugal force cannot produce heat, we conclude that the conduction of the current consists in forcing the corpuscles in rotation in such a way that they react from one molecule to the other between the poles.

When the current is closed through an electrolyte, the opposite takes place, namely, that the rotation of the corpuscles, which begins as soon as the positive radical is released from the negative, is checked, and the corpuscles brought back to molecular conditions by the circuital lines of force which traverse the electrolyte between the poles.

The density of the current must correspond to the formation heat of the salt in the same state, as in the electrolyte, and is divided into two parts, of which one separates and conducts the constituents to the corresponding poles, and the other, its complement, which checks the rotation of the corpuscles and restores them into molecular condition.

The concentration of the electrolyte, the distance between the poles, which all can be referred to a question of distance, come under the law of magnetic fields.

We have, consequently, no doubt in making the following statement:

When the current releases the negative radical from the positive radical, which is attracted and deposited on the negative pole, the corpuscles are in rapid rotation, and in order to stop this rotation and bring the corpuscles back to molecular condition, the current from that pole is consumed, no matter if the corpuscles are from metals or hydrogen.

The attraction and consequently the power to resolve a combination, depends on the electro-motive force at the poles.

A molecule can be considered as enclosed energy under a certain pressure equal to 22.3 x m atmospheres, which pressure is controlled by the attractive force of the corpuscles in the molecule.

This pressure acts according to our formula.

When an outside attraction takes place the opposite poles of all the corpuscles are turned against this new force, whereby the pressure is released and the centrifugal force is set in action.

All elements are thereby brought to the zero-volume number, for which a certain amount of energy, different for each element, is taken. When the attractive force from outside continues more pressure and consequently more centrifugal force is created.

The radio-active substances are just opposite to carbon, not only to look at but in the characteristic property that the corpuscles of carbon have a great affinity for each other. This affinity is the real cause that carbon does not volatilize except at the highest temperatures always forming new combinations, which makes its volatilization impossible. If it were not for this reason carbon would be volatile at 110° temperature.

The radio-active substances, on the contrary, have a very small affinity for each other, and if it were not for their disintegration into new elements, their properties could well be in harmony with other earthy elements, by which the centrifugal force is superior to the attractive force.

The heat evolved by chemical action can be calculated from the specific weight of the formed compound, which gives the number of the molecules per cubic meter.

This number must be multiplied by a coefficient to find the number of molecules per cubic meter for the components.

This coefficient depends on how many atoms the compound contains, and, as a general rule for the coefficient, the number of atoms must be divided by 2.

Some compounds with O and S hold O and S as atoms, and others as molecules with two atoms, in which latter case the number of atoms of the compound must be divided by 3. The valence must also be taken into consideration when the number of atoms is determined.

When Cl^2, Br^2, I^2 are contracted to half, or respectively to 46, 36 and 26 molecules per cubic meter, the coefficient is 2, when contracted to respectively 54, 42 and 33.5 molecules per cubic meter, the coefficient is 2.5, and when contracted more the coefficient is 3.

As we intend to come back to this subject, we will not at the present go into further explanation of the coefficient.

To illustrate that the energy can be calculated from the specific weight, we take K^2Cl^2, which weighs 1940 Kilos, and contains 13.2 molecules per cubic meter, multiplying this figure by 2 gives 26.4 molecules per cubic meter for the components.

Cl^2 has consequently been contracted 3.4 molecules per cubic meter from 23 molecules per cubic meter, which it contains at the boiling point.

As 5.4 was th eenergy per molecule per cubic meter, 3.4 points makes 18.4 Cal. K^2 is contracted from 7 to 26.4 with 19.4 points at 9.5 184.5 Cal.

In the same way by using the figures for energy per point, or number of molecules per cubic meter at the boiling point, which latter are given above, the energy in forming any combination can be calculated from the specific weight of the compound if the volume coefficient has been rightly calculated.

In a simple compound, up to 7 atoms, the energy has been calculated.

As the purpose of a chemical action is to bring the components to the same size, and the number of molecules per cubic meter varies from 7 to 115, it is evident that some element must expand when the others contract to form a combination, and that the number of points contracted or expanded is different from each element.

For instance, Cl^2 evolves 3.4 points in combining with K^2, 13 points in combining with Na^2, 24 points with Li^2, and 37 points with H^2. Cl^2 evolves, therefore, eleven times more heat when it combines with H^2 than with K^2.

The electric current, which represents the heat quantity when discharged is the product of the electromotive force and current, and it is necessary to have 23,300 Cal. to form one volt, wherefore the current cannot give any better explanation as to what amount of heat each compound contributes than has been brought out with thermochemistry.

There is no reasoning in saying that when 4.38 volts represent the combination of K and Cl, that 2.38 volts are due to K and 2 volts are due to Cl, because in this special case 92,250 Cal. come from K and 9,000 from Cl, which makes 3.99 volts from K and 0.39 volts from Cl.

Latent heat brings the balance of heat into the combination.

If a flame has a temperature of 1600° C. nobody would say

that 1200° belong to the oxygen and 400° to the carbon, and just as well nobody can say that 2 volts are produced from Cl and 2.38 volts from K, when combined.

Just as the temperature is not increased when latent heat is formed,—because the operation is an act of the attractive force,—so the current is not increased by latent heat.

A similar case is by neutralization, because the increased rotatory energy remains by the molecules, and no difference in specific weight occurs.

When, on the other hand, the electrical action takes place at higher temperature, the heat quantity evolved is in inverse proportion to the heat capacity.

If the specific weight should be taken of the electrolyte and of the deposited and dissolved metals in a battery before and after the current is produced, we are convinced that the difference in specific weight would correspond to the current. The same applies to concentration cells.

Chemical and electrical energy differ from each other only in that electrical energy originates in the corpuscles and chemical energy in atoms or molecules.

METHODS OF TESTING SLATE.

Methods of testing the elasticity, absorption, fissility, and resistance of roofing slates have been in use for many years, and many more or less complete chemical analyses of slate have been published. In recent years, however, more exact methods of reaching this results have been devised. All such methods have been brought together in the bulletin (No. 275) on the slate deposits and slate industry of the United States which Mr. T. Nelson Dale of the United States Geological Survey has recently prepared.

Tests are given by Mr. Dale for determining the sonorousness, cleavability, cross feature or "scalping," character of cleavage surface, presence of lime, the color and discoloration, the presence of clay, of marcasite, of magnetite, the strength, toughness or elasticity, density or specific gravity, the porosity, hardness or abrasion, and the corrodibility of slates.

One of the most satisfactory and decisive tests of slate, in the opinion of Mr. Dale, is the microscopic analysis. A thin section of slate examined under the microscope will suffice to show the character of the cleavage, the presence of false cleavage, if any, the probable durability, or indurability of the color, as well as the presence of any mineral constituents likely to determine its other qualities. Mr. Dale quotes Merriman to the effect that chemical analyses gvie only imperfect conclusions regarding the weathering qualities of slates and do not satisfactorily explain their physical properties.

Section of Physics and Chemistry.

(Stated meeting held Thursday, November 15, 1906.)

The Inspection of Imported Food Products.

By R. E. Doolittle,

Chief of New York Laboratory, U. S. Dept. Agriculture.

The Secretary of Agriculture was authorized by Acts of Congress of March 3rd, 1903, to inspect before entry into this country all foods, drugs, beverages and condiments of foreign production or manufacture. This law was embraced in the regular appropriation Act for the Department of Agriculture for the year 1903 and with slight amendments has formed a part of all subsequent appropriation acts for that Department. Congress at its last session also included the inspection of imported foods and drugs under the General Food and Drugs Act, and when this law goes into effect January 1st, 1907, the inspection of the imported foods will be carried on under the authority of the general law rather than the appropriation act. By the terms of the Act under which the inspection is now conducted, which is the Appropriation Act for Department of Agriculture of June 30, 1906, "The Secretary of Agriculture, whenever he has reason to believe foods, drugs, beverages, condiments or ingredients of these articles, are being imported from foreign countries which are dangerous to the health of the people of the United States, or which shall be falsely labeled or branded, either as to their contents or as to their place of manufacture or production, shall make a request upon the Secretary of the Treasury for samples from original packages of such articles for inspection and analysis and the Secretary of the Treasury is authorized to open such original packages and deliver specimens to the Secretary of Agriculture for the purpose mentioned, giving notice to the owner or con-

signee of such articles, who may be present and have the right to introduce testimony; and the Secretary of the Treasury shall refuse delivery to the consignee of any such goods which the Secretary of Agriculture reports to him to have been inspected and analyzed and found to be dangerous to health or falsely labeled or branded either as to their contents or as to the place of their manufacture or production; or which are forbidden entry or to be sold, or are restricted in sale in the countries in which they are made or from which they are exported."*

As is expressed in the text of the act the inspection of imported foods covers the following items:

(1) To ascertain whether or not the products are injurious to health.

(2) To ascertain if they be falsely labeled or branded; 1st, as to contents of packages; 2nd, as to their place of manufacture or production.

(3) To ascertain if they be forbidden entry to or are restricted in sale in the country in which they are made or from which they are exported.

To provide for the execution of this inspection act the Secretary of Agriculture has held† that in the absence of contrary judicial interpretation a food product shall be deemed to be adulterated

1st. If any valuable ingredient naturally present therein has been extracted.

2nd. If a less valuable ingredient has been substituted therefor.

3rd. If it be colored, powdered or polished with intent to deceive or to make the article appear of better quality than it really is.

4th. If it be a substitute for or imitation of a genuine article and offered under the name of that article.

It is also held in the absence of contrary judicial decisions that a product shall be deemed injurious to health

1st. If any substance, with the exception of the long-used, well known condimental substances, viz.: common salt, spices,

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*From Appropriation Act of U. S. Dept. of Agriculture, June 20, 1906.

†U. S. Dept. of Agric., Bureau of Chem., Circular No. 18, p. 2.

sugar (sucrose), wood smoke and vinegar, be added thereto for preserving, coloring or other purpose, which is injurious to health either as determined by actual experimental evidence or in the predominating opinion of health officers, hygienists and physiological chemists.

2nd. If a product be decomposed, filthy, decayed or in any unfit condition for human consumption.

A product is held to be misbranded

1st. If any false name or property be assigned thereto in the label directly or by implication.

2nd. If any false statement be contained in the label relating to the place of manufacture or production of the contents of the package directly or by implication.

3rd. If it be not of the nature, substance and quality commonly associated with the name under which it is sold or offered for sale.

Food products are also forbidden entry into the United States if they are of a character or kind forbidden entry in the country where they are manufactured or from which they are exported.

Both the Department of Agriculture and the Treasury Department are concerned in the execution of the imported food inspection law. The Treasury Department has possession of all imported goods and the officials of that Department, upon request from the Department of Agriculture, take and deliver all samples to the Department of Agriculture for inspection and analysis. When a product is found adulterated within the meaning of the law the Treasury Department secures the reshipment of the goods when so requested by the Department of Agriculture.

To give you a proper idea of the manner in which the inspection work is now carried on it is necessary to consider briefly certain procedures in the Customs service of the Treasury Department. In the execution of the customs law it is required that a ship coming to a port in this country from a foreign country shall make entry at the Custom House, i. e., the master must file the clearing papers from the sailing port and a manifest of the entire cargo; and it is further required that within forty-eight hours after a ship makes entry all consignees of merchandise on that vessel shall also make entry at the

Custom House, filing a copy of the consular invoice covering their respective shipments of goods. A consular invoice, as its name implies, is a list of the items of merchandise, with their foreign values, together with all items of expense, all of which is certified before the United States consular officer of the port from which the goods are exported. (Exhibit No. 1.) From this invoice the approximate duty is quickly estimated and this sum paid by the importers. I may note that after the merchandise has been appraised the invoice comes back to the liquidating officers of the Custom House and any excess duty paid is returned to the importer or if sufficient duty has not been paid this must be advanced before a release of the shipment is given. But to return to the regular order of procedure. After the importer pays the estimated duty permits are given in most shipments of general merchandise for removal from the docks of all but the Public Store cases, a bond being required for their return should they be demanded for any purpose by the Government. At least one case in every ten of all case goods is sent to the Public Stores for appraisement purposes, i. e., for comparison with the invoice and fixing of values. The invoice is sent direct from the Custom House to the Appraiser's warehouse and after proper recording reaches the examiners who appraise the merchandise. It is while the invoice is in the hands of the examiner that the inspection is made by the Department of Agriculture under the Food Inspection Act.

It, perhaps, is worthy of note to mention, at this point, that when the Inspection Law first went into effect, which was July 1, 1903, the work was all done through the Bureau of Chemistry at Washington. Arrangements were made with the Department of State whereby copies of all invoices of food products were sent direct to the Bureau by the American consular officers of the different countries. From these copies of the invoices samples were requested from the Secretary of the Treasury and these samples were forwarded to Washington by the Collector of Customs at the port where the goods were entered. The delay occasioned by the transmission of samples and correspondence so inconvenienced the importers and the customs officers that it was decided to try the plan of having laboratories at the principal ports of entry. The first port

laboratory was opened in the city of New York September 6, 1904. The success of this laboratory in facilitating the inspection work has resulted in the establishment of laboratories at five of the other ports, viz.: Boston, Philadelphia, New Orleans, Chicago and San Francisco. Shipments arriving at ports at which there are no laboratories are inspected at the Bureau of Chemistry in Washington by means of the copies of invoices sent direct by the consular invoices.

The inspection by means of the copies of invoices sent direct was not satisfactory for the working of the port laboratories for the reason that it was not complete. Often the goods arrived and were passed by the Customs officials before the Department copy of the invoice was received, and again, the consular officials often neglected to send the Department copy or it was lost in the mails; as a consequence one importer's goods were passed while another's, perhaps of the same kind, were detained. It, therefore, became necessary to devise a new system of inspection and after a thorough investigation by both Departments the present scheme of inspection of the regular invoices entered by the importer while these invoices are in the possession of the examiner of the merchandise was adopted. This is carried out as follows: The inspecting officer of the port laboratory visits, generally at certain hours of the day, the various examiners having the appraisement of food products. Here all invoices are open for his inspection; in fact, no invoice containing an item of food product is permitted to be returned by an examiner until it has been inspected by the representative of the Department of Agriculture. If, on examining an invoice, the inspector finds no item from which he desires a sample he stamps the invoice "No Sample Desired by Department of Agriculture" (Exhibit No. 2.) An invoice thus stamped may be returned or passed to another examiner without further detention. If, however, a sample is desired from some item contained on the invoice the inspector attaches to that invoice a small tag on which he indicates the marks and numbers of the particular case to be sampled, the name of the substance and the amount of the sample. Data are also taken for the record of the sample, a copy of which is filed with the Chief Clerk of the Division for checking the invoices when returned. (Exhibit Nos. 3 and 4.) When a sample has been re-

quested from an invoice the examiner at once notifies the importer that such sample will be taken and that he is requested to hold intact the remainder of the shipment until the examination is completed and he is further notified from the Department of Agriculture. (Exhibit No. 5.) It also becomes the duty of the examiner to secure and forward to the laboratory of the Department of Agriculture without delay the sample requested. (Exhibit No. 5a.) An inspector is often unable to determine by the examination of an invoice whether or not a sample will be required. This is particularly true of the inspection to determine whether or not the goods are properly labeled as to country or production or manufacture. Repeated analysis of certain brands of merchandise also informs an inspector as to their composition and it then becomes only a matter of inspection of labels to determine whether or not the goods are entitled to admission. In all such cases the inspector attaches to the invoice a detention slip. (Exhibit No. 6.) When such detention slip is attached to an invoice the inspector's attention is called to the Public Store cases indicated thereon when they are opened for appraisement by the customs examiner. In substance, the inspection work, therefore, resolves itself into the examination of all invoices containing items of food products and the examination of all Public Store cases of food products when the cases are opened for appraisement purposes. The latter examination is called the floor inspection and is made at the same time the inspector visits the examining rooms for the inspection of invoices.

The floor inspection greatly facilitates the work at the laboratory as it greatly lessens the number of samples sent there for examination. As is well known, the question of adulteration is often a question of the label. If the label correctly informs the purchaser of the contents of the package and analyses have shown a certain brand of goods to contain no substances prohibited by the statute it then becomes only a question of examination of the label which can be as conveniently and as well done on the examining floor as in the laboratory. If, on examining the cases the inspector finds the goods properly labeled he simply removes the detention tag and stamps the invoice "No Sample Desired." If, on the other hand, he

finds an article not properly labeled or one the nature of which he does not know, a sample is requested in the regular way.

In the case of goods examined on the docks, such as bulk wines, liquors, fruits, spices, etc., samples of the merchandise are requested direct from the invoices in the usual manner and are obtained by means of sample tickets forwarded by the examiner to the samplers on the wharf.

When a sample is received at the laboratory it is submitted to such examination as is necessary to determine whether or not it is prohibited under the provisions of the law. It is necessary that there be no delay in this examination for the importers often sell goods on arrival and are anxious to be permitted to dispose of their shipments. Most samples are reported within twenty-four hours after they are received. Certain products, however, require a longer time for analysis. Generally speaking, all samples are reported within forty-eight hours after they are received. If the goods are found to comply with the law the importer is notified immediately upon completion of the analysis that the examination has been completed and the shipment need not be further detained. (Exhibit No. 7.) If the goods are found to be in apparent violation of the law the importer is notified of the alleged violation and a date fixed at which evidence may be presented and the case will be taken up for final disposition. (Exhibit No. 8.) At the same time that the importer is notified of an alleged adulteration the Collector of Customs for the port is also requested to secure the actual possession of the goods and hold same for final action. (Exhibit No. 9.) A sample of the product is sent to the Chief of the Bureau of Chemistry at Washington with a copy of the analysis and such data as the Chief of the Laboratory may have concerning the shipment, importer or manufacturer. The analysis is repeated by the Washington laboratory and a report made confirming or reversing the port recommendation. These results, recommendations and all evidence submitted by the importer are carefully considered in the final decision of the case by the Chief of the port laboratory. If the goods are found to be in violation of the law the Collector of Customs for the port is requested to secure their reshipment beyond the limits of the United States. (Exhibit No. 10.) If it be found that the goods are not in violation

of the law the Collector of Customs is requested to release the shipment from further detention in so far as the Department of Agriculture is concerned.

In the enforcement of the law the Department has been very lenient with the violators. For a considerable length of time when a shipment was found to be in violation of the law but the adulterant was not positively injurious to health the shipment was released with a warning to the importer and explanations of the requirements of the Act. Afterwards permission was given to correct the labels on goods already packed by the use of supplementary labels and pasters. At the present time, except in first instances, goods that are in violation of the law are required to be shipped beyond the boundaries of the United States.

It will, perhaps, be of interest if we consider some of the products that are inspected at the port laboratories and the forms of adulteration found. At the port of New York the number of invoices of food products is so large that up to the present time it has been impossible with the force of men and laboratory space at our disposal to inspect all lines of products. To one not acquainted with the Customs service it is difficult to appreciate the volume of merchandise that passes through the port. I am informed that last month between eight and nine thousand invoices of food products were passed. Of course, many of these cover shipments of whole fruits, vegetables and similar products that require no further inspection than the stamping of the invoices. But the great majority of them cover shipments of miscellaneous products and vary from one to a dozen or many thousand cases. Each of these invoices is accompanied by a declaration of the manufacturer or shipper of the goods. This declaration gives the country where the products were grown, place where manufactured and statement of the presence or absence of preservatives, coloring matters, or other foreign substances. (Exhibit No. 11.) With this declaration on all invoices we are able even without the analysis of the products to gain some knowledge of their character. Certain lines of products, however, have been taken up and the inspection made complete in every respect. By this I mean every shipment of that line of merchandise was inspected. Samples of all sihpments were taken and subjected to thor-

ough chemical examination. After it was ascertained what brands or which manufacturer's goods were in compliance with the law further shipment were sampled only at intervals to see that no change was made in their composition. Those found not in compliance were detained in each instance until the manufacturer made the proper correction either in the character of the products or the manner of labeling as the case might be. In this manner we have covered at the port of New York the various fruit products as jellies, jams, preserves and marmalades; the canned vegetables as peas, beans, tomatoes, spinach, asparagus, etc.; the prepared meats as sausages, pate de foie gras and potted meats; sardines, ground spices, vinegar, lemon oil, olive oil and egg products.

Regarding the forms of adulteration that are practiced in these various lines of product I would say they are practically the same as are found in domestic products of the same kind. In the jellies, jams, preserves and marmalades, glucose was commonly substituted for cane sugar, coal tar dyes and cochineal were frequently used for coloring purposes and salicylic acid was very commonly present as a preservative. It always seems strange to me that manufacturers will insist that they must color their prepared fruits a bright color. I recall one instance, a shipment of canned peaches presented for entry in which the goods were colored a bright red. They were labeled red peaches. I suppose the manufacturer thought the unsophisticated Americans would believe they were getting a new variety of peach. Some fruits are even colored green with sulphate of copper. It was exceedingly difficult for some of the English and Scotch manufacturers to discontinue the use of glucose and the small amounts of salicylic acid in their jams and marmalades. They made the same claim as commonly heard from our own manufacturers that the glucose was necessary to prevent the crystallizing of the sugar. The Department did not prohibit the use of glucose but it did require that when it was used the fact should be stated on the label. As a consequence every manufacturer discontinued its use, at least in the products shipped to this country, and I have never heard any complaints for reason of the sugar crystallizing. The use of preservatives such as salicylic acid is to my mind the worst of all these forms of adulteration. Not only have experiments

proven that these preservatives are positively injurious to health but their use enables manufacturers to use products and methods of preparation that are even more dangerous to the health of the consumer than the chemicals themselves. The use of preservatives puts a premium upon filth. Their use destroys all incentive for cleanliness and scientific principles in the selection and preparation of the products. I believe it is a true statement that where you find a manufacturer of fruit preserves uses preservatives in his product you will find that his factory, apparatus or containers are not in a proper sanitary condition. I know there has been a great change in the character of the preparation of this class of products that are brought into this country since the use of preservatives was prohibited. Jars have been changed in form and scientific methods of sealing adopted, in fact the whole nature of the product altered. This is also true of the German sausages. Boric and benzoic acid were used almost universally in the canned sausages supplied to this country. And this in a way was very peculiar, for Germany has very stringent laws which prohibit the use of these preservatives in the products used in their own country. Therefore by the wording of the law, which I have already quoted to you, these goods were prohibited entry into this country. What was the result? It cost the American importer from one to two dollars a case more for the sausages, for, as one manufacturer wrote, "We have to put up the sausages in sterilized water." Outside of the use of preservatives very little adulteration has been found in the imported meat products. One or two instances of the use of potato flour have been detected. By the regulations formulated for the enforcement of the new food law which goes into effect the first of next January all shipments of meat and meat food products will have to be accompanied by a certificate of official inspection of a character to satisfy the Secretary of Agriculture that they are not dangerous to health.

In the canned vegetables another class of coloring matter and preservatives was found. As is well known, nearly all canned French peas and beans are colored with sulphate of copper. The Secretary of Agriculture has ruled that "Pending investigations that are now making, all food products colored with sulphate of copper or to which sulphate of copper

has been added for any purpose should contain upon the label a statement in English in letters not smaller than long primer caps "Colored With Sulphate of Copper," or if preferred "Prepared With Sulphate of Copper." As a result all the peas and beans, macedoine and spinach now bear a statement upon the label that they are colored (or prepared) with sulphate of copper. In the canned asparagus sulphites have been found, and practically all canned mushrooms show small amounts of sulphites due to the bleaching process to which they are submitted. Soon after the inspection work was begun at the port of New York we found that there were being entered at that port large quantities of mushrooms labeled "Champignons d'Hotel," hotel mushrooms. An examination of these goods revealed the fact that they consisted of only waste pieces, the refuse from the canneries. Such products are now labeled "Champignons, Pieces and Stems." Large quantities of canned tomatoes and tomato paste are imported into this country from Italy and salicylic acid and benzoic acid were found in many instances when the inspection of that line of products was taken up.

Another product which was largely adulterated when the inspection was first begun was olive oil. Peanut oil and sesame oil were the adulterants most commonly employed. At present I believe I am safe in saying that not an ounce of the adulterated oil is entered at the ports where laboratories are established. But this does not mean that the consumer is obtaining the unmixed oil. The oils are simply brought over separately and mixed on this side. It is not a strange thing to see on the same invoice so many barrels or tins of olive oil and so many barrels of peanut oil. I do not know of any very extensive use for peanut oil in this country except as an adulterant for olive oil. A fraud which is commonly practiced and one which at the present time is giving the Customs officials considerable difficulty is the practice of certain Greek and Italian merchants who bring over oil to which they have added the "footings" or settlings from olive oil casks. This they enter as machinery oil. The duty on edible olive oil is 40 cents a gallon, while oil fit only for manufacturing purposes is free. After the oil is received it is allowed to stand for a length of time and settle or it is filtered and then the clarified product

is mixed one-half or two-thirds with cotton seed oil and put on the market for pure olive oil. These are practices which the present import inspection law cannot stop, but when the general food law goes into effect it is expected that wherever these products enter interstate commerce we shall be able to compel them to be sold for just what they are. In connection with the oils we have also inspected the sardines and other fish packed in oil. Formerly practically all sardines were labeled "Sardines a l'huile d'olive" or "Sardines packed in olive oil." As a matter of fact we found that the oil in a great many of the shipments was peanut or sesame oil or a mixture of these oils with olive. It is claimed that in France the fish are cooked in peanut oil, and after draining, are placed in the tins and covered with olive oil. Fish cooked in peanut oil do not turn so dark is the reason advanced for the use of the peanut oil. As investigations showed this to be the actual practice the Secretary of Agriculture has for the time being allowed all shipments containing not to exceed 5% of peanut oil to be entered even if labeled "Packed in olive oil." Another deception which is practiced in the sardine trade is the selling of Belgium or Portuguese sardines for the French product. This is also true of Italian and Belgium peas and beans which are represented as the French. The Treasury law requires that every package shall be labeled in such a manner as to indicate the country of origin. But the importers succeed in putting on the name of the country in such an inconspicuous manner while all the reading matter on the tin is in French with a fancy French brand that the ordinary consumer is deceived in his purchase of the goods. I am not saying that the Portuguese sardine or the Italian beans are not as good as the same product from France. But if they are as good they need not be sold under a French label. If they are not as good, and the prices would indicate they are not, then their sale as a French product is plainly a deception. It all resolves itself to the basis of all food laws; let the label tell the truth.

A product with which we have had considerable trouble in our inspection work and one which is not commonly met with in the domestic goods is liquid eggs. Soon after the laboratory was established at the port of New York we discovered that large quantities of this liquid egg were being brought in every

month and that it was preserved with about 2% of boric acid. Liquid egg is simply broken egg with shell removed. The goods came mostly from China and I understand are the eggs of the wild fowls of that region. It was used by the large bakeries and restaurants of the cities. The importers were very shrewd in bringing in the product, which they entered as "Chemical Compound," the chemical being boric acid, I suppose. The Department soon stopped all shipments of this class of goods. Large amounts of the dried albumen are received every year and occasionally a shipment of dried yoke or dried whole egg. These, however, must be free from preservatives or they are not allowed entry. Salicylic acid and fluorides are the other preservatives which have been found in this class of products.

Regarding the other products which I have enumerated as having been subjected to inspection there is none which differs enough from the domestic product to warrant discussing it at length. Practically all of the vinegar imported is the wine vinegar of France and Germany and the malt vinegar of England. Numerous cases of substituted distilled vinegar colored with caramel and the diluted products were found, but as the importers were being defrauded we have had but little difficulty in stopping the importation of these fraudulent articles. Paprika is practically the only spice brought into this country in the ground state. As this sells on its color almost entirely we have found a great many instances of the artifically colored product, the red coal tar dyes being used. A great amount of refuse spice products is imported annually, such as exhausted ginger root from the ginger ale factories of England, pepper hulls, worm eaten nutmegs and the refuse from the paprika grinders, but I thought I had found the limit when some time ago I detected a large shipment of exhausted clove stems. I remember when in the State food inspection work a prominent spice grinder tried to convince me he could not grind his cloves without using a percentage of cloves tems. I can understand it better now. However, judging from the character of this sample, the little branches of any dead tree would have done just as well.

In my discussion of the adulterated products you will probably wonder why I have not taken up the subject of wines and

liquors, which form a great bulk of our imports. I have not discussed these products for the reason that I am not as yet prepared to do so. We have done very little work along these lines at the port of New York, practically none of real inspection. Considerable research work has been done by the Department and some day we will be prepared to give you a whole evening's discussion of this important subject. I may say in passing that the non-alcoholic beverages, as ginger ales, sarsaparilla and the various fruit juices have been thoroughly inspected, and while they formerly were in many cases preserved with salicylic acid, benzoic acid, or sulphurous acid, these preservatives are now seldom used in any of these products with the exception of limejuice. Most limejuices contain sulphurous acid and this fact is stated on the label.

The results obtained by the enforcement of the inspection act offer much encouragement to all interested in the securing of pure food products. There has been a marked change in the character of all foods imported into this country. Many products that formerly contained preservatives and coloring matters are now free from these added substances. That to the consuming public means much more than danger that might arise from the consumption of the products containing these ingredients. It means that the consumer may know that he is getting just what he calls for; and it means that the manufacturer has produced his product from sound healthy substances in a clean scientific manner and stored them in clean properly sealed containers. As the manager of a large manufacturing concern told me some time ago, "We have got to change our business and put it on a scientific basis. We have always used preservatives for the reason that it was the easiest way. It really is the lazy man's method." And so it is. I, for one, do not believe that what we are to eat can be too carefully selected or too carefully prepared.

It is encouraging to those interested in the enforcement of the law to note the attitude that was assumed by the importers from the very beginning. Of course, there are among the importers at the different ports, as in all other branches of business, some who can only construe the law as enacted particularly to destroy their business and who will not make a change in their products or a correction in their labels except as they

are absolutely compelled to do so. Their sole object seems to be to see how much they can violate the spirit of the law and yet succeed in entering their goods under the strict interpretation of the Act. But the majority of the importers have favored the law and have supported the officials in its enforcement. With them, to correct a violation it has only been necessary to explain what the violation was and then give time to get the matter corrected on the other side. Perhaps the greatest difficulty, at least one of the worst, has been to get the manufacturers on the other side to understand our requirements and to make the change. These manufacturers are for the most part people speaking another language and separated from us by the broad space of the Atlantic. They have produced their goods in the same manner for years and they cannot understand why we should now demand a change. Another difficulty has been the fact that certain lines of products are put up when there is abundance of that product and then the goods are kept on hand for years. This is true of such products as sardines. When there is a good run of sardines the packers put up all they can catch, for there is no telling how long it will be before there is another catch. One importer told me the other day he had tins for 10,000 cases of sardines held over from last year and so far this year he had packed 34 cases. These are difficulties we have to meet and the Department always takes all such matters into consideration in deciding each individual violation. Our present law is far from perfect, but many of its defects are corrected in the Food and Drugs Act which goes into effect January 1st, 1907; and from the assistance that will accrue from a law governing the domestic as well as the imported goods it is expected much better results will be obtained from the enforcement of the law in the future. The port inspection work has but nicely begun. There are many and important lines of products not subjected to proper inspection. Complaints are constantly being received concerning the adulteration of certain products. The truth of these must be investigated before the real inspection of those products can be begun. In fact, there is always a certain amount of investigation to be done before any new line of inspection can be taken up. The work of the port laboratory is by no means confined to the analysis of samples from

the shipments inspected. Studies on the composition of products, detection of adulteration and methods of analysis must be kept constantly under way. However, a great change for the better has already been accomplished on the products inspected and with the advent of the new law and the increase contemplated in the inspection force it is expected greater and better results will accompany the work in the future.

PRODUCTION OF COAL IN CALIFORNIA DURING 1905.

The total production of coal in California during 1905 was 77,050 short tons, valued at $382,725. These figures are taken from the report of Mr. E. W. Parker of the United States Geological Survey.

The principal feature of interest connected with the production of coal in California has been the apparently successful efforts to utilize the lignite or sub-bituminous coals produced in the State in the manufacture of briquettes. During 1905 there were four of these plants in operation. One, at Stockton, was operated by the San Francisco and San Joaquin Coal Company, which used the lignite or sub-bituminous coal produced at the Tesla mine owned by the same company. Unfortunately, this plant was entirely destroyed by fire in November, 1905, and the plans for its rebuilding, this time at San Francisco, have been interrupted by the earthquake and fire which nearly destroyed that city in April of the present year. Another plant constructed in Oakland by the Western Fuel Company upon designs prepared by Mr. Robert Schorr, of San Francisco, was put in operation during the latter part of the year. The third plant, a small one, owned by the Ajax Coal Company, of San Francisco, was in operation during most of the year, and the fourth, which was built at Antioch, was not completed until the latter part of the year. All of these plants were constructed for the purpose of using the California lignites or sub-bituminous coals, sometimes with and sometimes without a mixture of "Wellington" and other bituminous screenings obtained at the coal yards, and using asphaltic pitch as a binder. This pitch is obtained as a residue from California crude petroleum which when properly distilled yields a pitch possessing excellent binding qualities.

Mining and Metallurgical Section.

(*Read by title at the Stated Meeting held Thursday, January 31, 1907.*)

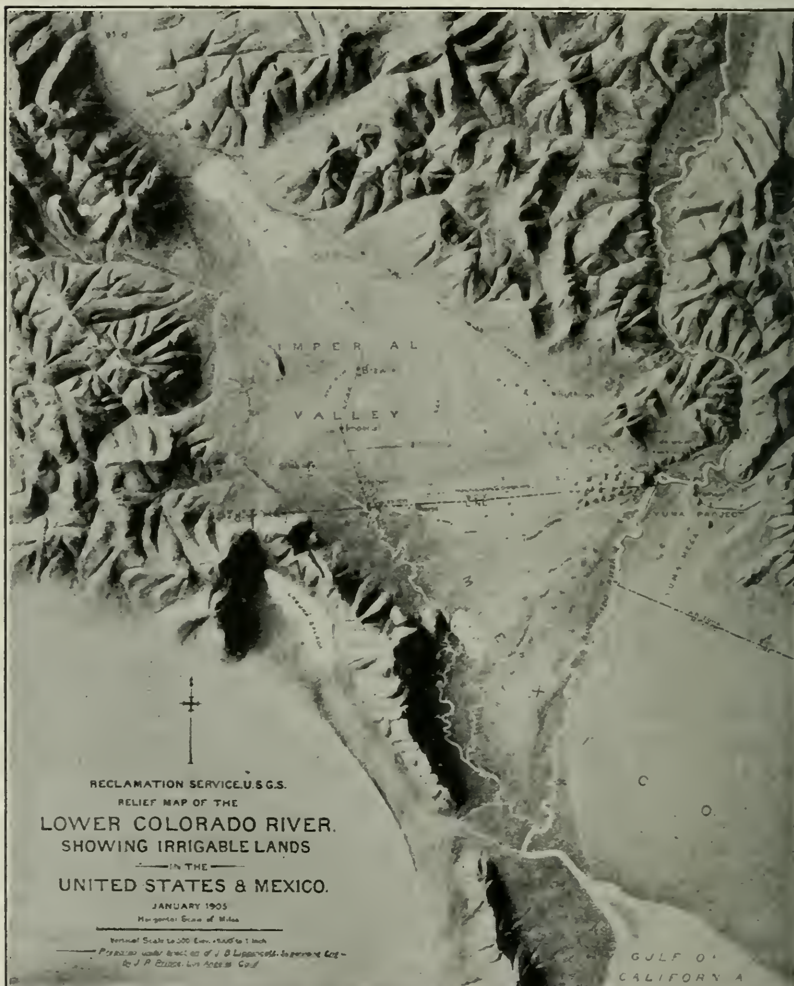
Irrigaticn and the Government Irrigation Project at Yuma.

PROF. OSCAR C. S. CARTER.

Primitive man was doubtless carnivorous much more so at least than is his brother to-day, but there came a time at last in the history of man when his attention was drawn to the vegetable world as a source of food supply; just when or where this was is a question. There is no doubt that environment influenced the food supply of early man as it does to-day his more or less civilized brother. Environment makes the Esquimaux a flesh-eater and the Indian of the tropics more or less of a vegetarian. When man first began to till the soil in arid or semi-arid regions he learned that water was necessary to plant growth and thus received his first natural lesson in scientific agriculture. Irrigation, history teaches us, was practiced centuries ago; it is a very ancient art. It is said the ancient Egyptian, Hebrew and Oriental records contain many references to irrigation. There are remains of ancient irrigation works in Europe, Asia and parts of Northern Africa.

The art of irrigation in Egypt is very ancient; they had extensive systems of lakes, reservoirs and canals, so it is said, as early as the time of Sesostris. Early irrigation was also practiced in Persia, China and India. The Romans practiced it in Italy and the Moors in Spain, Sicily and Algeria. Irrigation has been practiced recently in France to destroy the insect pest phylloxera of the grape vine by submerging the roots. In the arid regions of the Southwest near the Gila, Salt and Verde Rivers, in Arizona, near streams in New Mexico, and near the Rio Virgen in Nevada, are found ancient irrigation ditches, some of which are of great length. These were used

by the aborigines centuries before the time of Columbus. Some of these show considerable engineering skill in their construction, at least good judgment in the selection of sites and great patience in their construction, particularly where



they are cut through solid rock. In the 13th Annual Report of the Bureau of Ethnology is an article by Cosmos Mindeleff on Aboriginal Remains in Verde Valley, Arizona. On page 194 he states: "Irrigation ditches and horticultural works

were found in this region. Fine examples of irrigating ditches were found at the extreme northern and extreme southern limits of the region treated and there is a fair presumption that other examples occur in the intermediate country. These works did not reach the magnitude of those found in the Gila and Salt River Valleys, perhaps, partly for the reason that the great fall of the Verde River renders only short ditches necessary to bring the water out over the terraces." Page 238 he states: "One of the finest examples of an aboriginal irrigating ditch that has come under the writer's notice occurs about two miles below the mouth of Limestone Creek, on the opposite or eastern side of the river. At this point there is a large area of fertile bottom land, now occupied by some half dozen ranches, known locally as the Lower Verde Settlement. The ditch extends across the northern and western part of this area. Plate XXXIV shows a portion of this ditch at a point about one-eighth of a mile east of the river. Here the ditch is marked by a very shallow trough in the grass-covered bottom, bounded on either side by a low ridge of earth and pebbles. Plate XXXV shows same ditch at a point about one-eighth of a mile above the last, where it was necessary to cut through a low ridge. North of this point the ditch cannot be traced, but here it is about forty feet above the river and about ten feet above a modern (American) ditch. It is probable that the water was taken out of the river about 2 miles above this place, but the ditch was run on the sloping side of the mesa which has been recently washed out." "On the southern side of Clear Creek about a mile above its mouth there are, near the ancient village ruin, extensive works covering a large area of the terrace or river beach, for a distance of two miles east and west along the creek and perhaps a half a mile north and south there are traces of former works pertaining to horticulture, including irrigating ditches, reservoirs, farming outlooks," etc.

In South America there are aqueducts which are used to carry water for miles for irrigation and other purposes. They were constructed by the early Indians. Enough has been said to draw attention to the fact at least that irrigation is not new in this country. Mr. E. A. Beals, Official Forecaster of Weather Bureau, states in Year Book Agriculture, 1902, that "Excluding the rice-irrigation system of China, Japan and

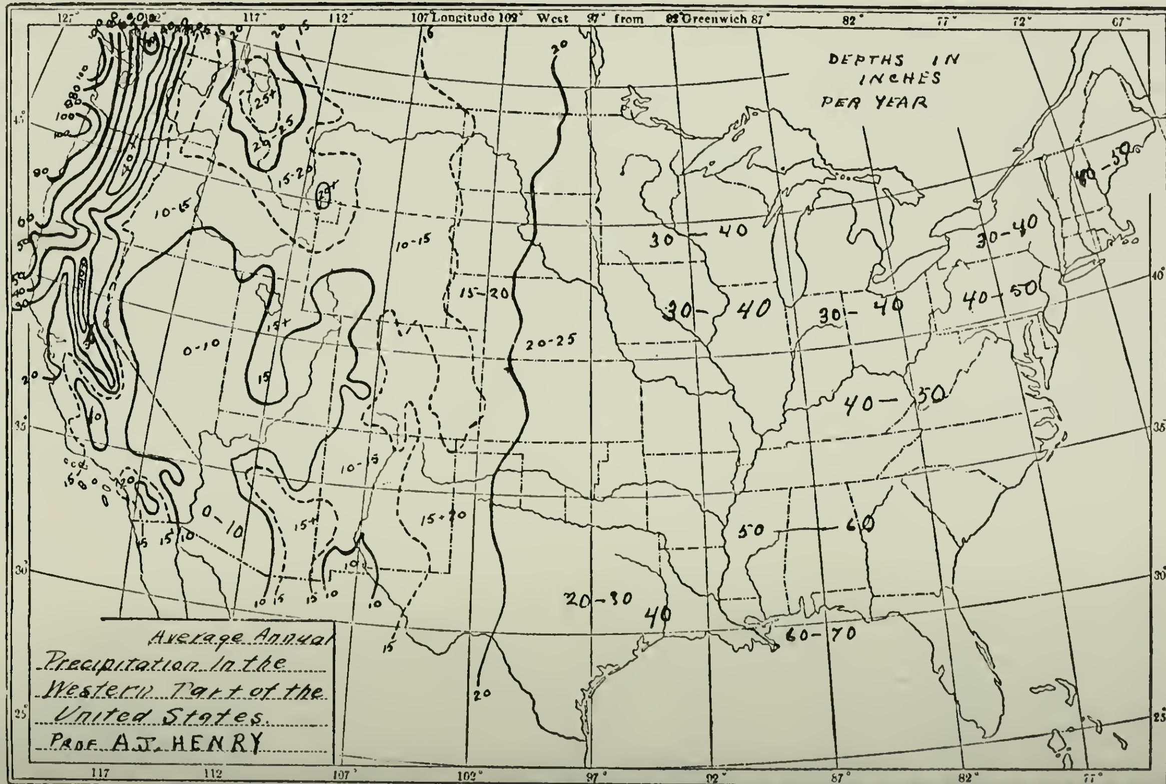
S. E. Asia, there are some fifty or more millions of acres of irrigated land in the world, and of this great area fully one-half is located in countries having a humid or semi-humid climate with an annual rainfall above twenty inches. The really arid lands are confined to scattered sections in the western half of the United States, Argentina and in the valley of the Nile below Assuan, some 500 miles from Mediterranean Sea.

IRRIGATION IN INDIA.

"The most extensive system of irrigation is in India where at least 25,000,000 out of a total cultivated area of 144,000,000 acres are irrigated. The principal canals are in the Ganges and Indus valleys, but they are found in nearly every province of the country. Besides canals built under the direction of the government thousands of small reservoirs are distributed throughout the empire. The crops raised from this water support at least 20,000,000 people. The melting of snows on the Himalayas during the hot months of March, April and May furnish water to the canals in Northern India. The rainfall is unevenly distributed, decreasing rapidly from 115 inches near the Himalaya foothills to six inches in the upper Sind province, less than 350 miles away. The greatest known rainfall in the world occurs on the southern slope of the Himalaya Mountains about 200 miles back from the Bay of Bengal. The rainfall at an elevation of 4,455 feet averages 474 inches yearly, nearly all of which falls during the five months from May to September, and as high as forty inches have been measured in a single day. On the Deccan plateau the rainfall is only twenty inches per year.

IRRIGATION IN EGYPT.

"The lower valley of the Nile, including its delta, comprise another great irrigation system with over 6,000,000 acres under cultivation. Egypt is wholly different from India as far as rainfall is concerned, being so arid that dry farming is impossible. The irrigated area begins at Assuan, about 500 miles from the Mediterrancan Sea. The valley above the delta is


Longitude West from Greenwich
DEPTHS IN INCHES PER YEAR
Average Annual Precipitation In the Western Part of the United States.
PROF. A.J. HENRY

narrow with a tillable breadth averaging less than nine miles. At Alexandria the annual rainfall is 8.8 inches. The annual amount at Cairo is 1.3 inches. As far as crops are concerned the annual rainfall in the irrigated sections of Egypt might as well be ignored. The waters of the Nile are supplied by heavy rains in equatorial Africa near Lake Victoria, Lake Albert and Lake Edward. Here the rainfall is eighty inches per year. These reservoirs keep the Nile from running dry through the long stretch of desert, as it would probably go dry otherwise before reaching the sea. The dam just completed at Assuan has a storage capacity of over 30,000,000,000 cubic feet. It is built of granite and is seventy feet high, twenty-three feet wide at the top, eighty-two feet wide at the bottom, and one and one-fourth miles long. It will regulate the supply of water and natural flow, which is too high during three months of the year and too low during the remaining nine months.

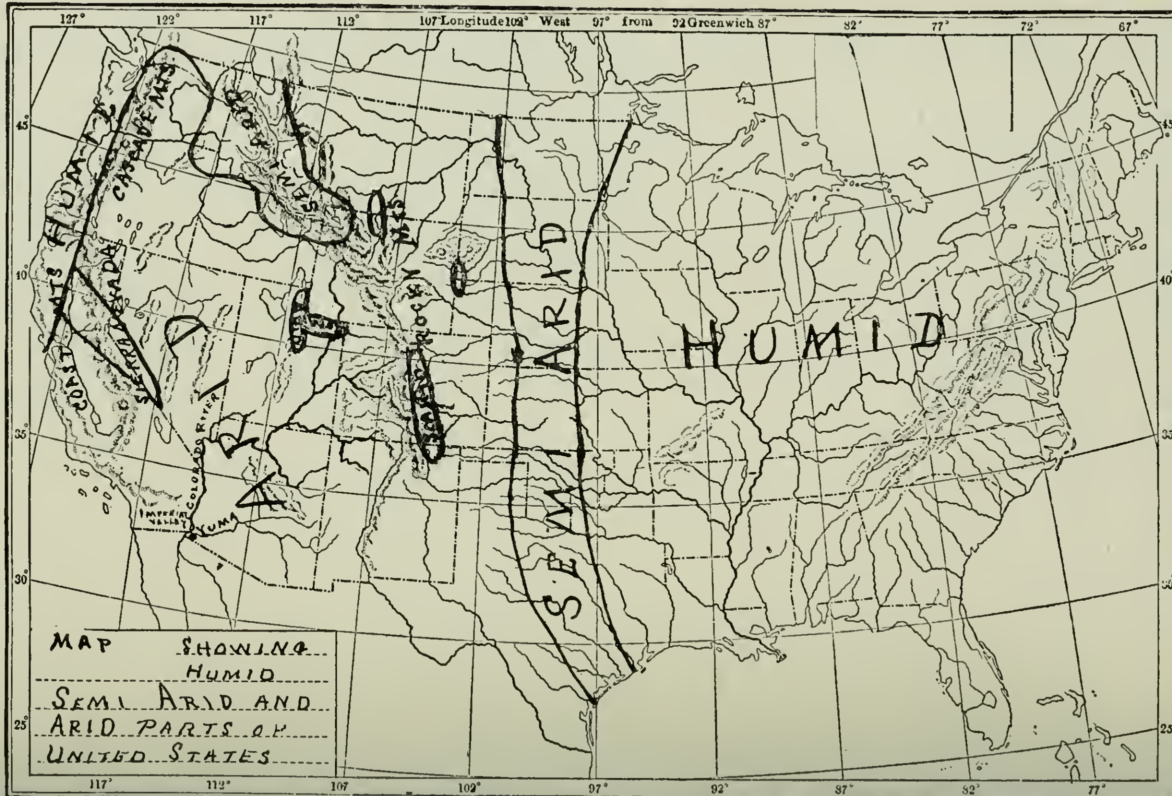
"Italy has irrigated since the time of the Romans and has 4,715,000 acres under irrigation. The rainfall varies from twenty to thirty inches per year. Spain has about 5,000,000 acres under irrigation. On the north coast the rainfall is heavy, over fifty inches per year. Near Madrid the rainfall is seventeen and one-half inches and it is less farther south. France has about 5,800,000 acres under irrigation. Near the English Channel the rainfall is forty inches. At Paris, twenty-two inches. In Southern France, about twenty-five inches. The summers are dry. In Australia little has been done for irrigation, but much has been planned. The rainfall is slight and droughts are frequent. The last three years have been droughty and it is reported that out of a total of 120,000.000 sheep at least 40.000,000 have died on account of drying up of the pastures. The rainfall for the continent of Australia is about twenty-one inches. He states the small rainfall is due to the fringe of mountainss skirting the continent, which are not high enough to collect snow, and therefore it will never be possible to irrigate much land even if all the water be utilized.

"In South America irrigation is confined principally to Argentina; the rainfall varies from three or forty inches per year. In the country of the Incas before the Conquest irrigation was practiced much more extensively than it is to-day."

His above brief extracts on irrigation in India, Egypt,

Europe and Australia are quoted because they will help us by comparison to understand better the conditions as they exist in the United States as regards rainfall and other climatic changes and also the areas under irrigation and to be irrigated. That portion of the United States east of the 100th meridian has a humid climate. The 100th meridian passes through about the middle of the Dakotas, Nebraska, Kansas, Oklahoma and Texas. The rainfall east of the 100th meridian varies considerably. In the Southern States it varies from fifty to seventy inches per year. The southern parts of the States that border on the Gulf of Mexico have a rainfall of seventy inches. The Middle States have a rainfall of from thirty to fifty inches per year and in the New England States the rainfall varies from forty to fifty inches per year. The States that border on the great lakes have a rainfall of from thirty to forty inches, so have Iowa and Missouri, but the rainfall decreases as we go farther west, and the eastern parts of those States through which the 100th meridian passes have a rainfall of from twenty to thirty inches. Between the 100th meridian and the country east of the foothills of the Rockies, roughly speaking, there is a stretch of country which might be called semi-arid. It takes in Western Kansas, Nebraska and Oklahoma and parts of the Dakotas. West of the semi-arid region the United States is arid except Northern California, Western Oregon and a large part of Washington. We might say in a general way that the United States is mostly an arid region between the 100th meridian and the Pacific Ocean. The author would like a classification somewhat as follows: An arid country is one in which the rainfall is from two to fifteen inches per year, and in a semi-arid country the rainfall varies from fifteen to twenty-five inches.

The able Chief of the Reclamation Service says that in a general way it may be said that arid regions are those where the average rainfall is twenty inches or less. According to this the arid regions of the United States include more than two-fifths of the entire area. He says: "As a matter of fact, however, a great part of the countries of the Old World have less than twenty inches annual rainfall and therefore according to our standards must be considered arid. The civilization of former times, however, grew up in those arid regions and we


MAP SHOWING HUMID
SEMI ARID AND
ARID PARTS OF
UNITED STATES
HUMID
SEMI ARID
ARID
COAST MTS
SIERRA NEVADA
CASCADE MTS
ROCKY MTS
COLORADO RIVER
IMPERIAL VALLEY
YUMA
Longitude West from Greenwich
127°
122°
117°
112°
107°
102°
97°
92°
87°
82°
77°
72°
67°
45°
40°
35°
30°
25°

cannot fully appreciate the writings of the ancients and the true meaning of many familiar phrases handed down to us without bearing in mind the fact that the writers lived in an arid climate where agriculture was successful only through irrigation."

We would like, however, a distinction made between an absolute desert where almost no verdure grows and the rainfall is only say three inches, and a section of country where the rainfall is eighteen inches and verdure is abundant, providing of course the rainfall comes at a time of the year when it will do some good. In considering the rainfall of a country we must know whether the rain falls at the time of year when the growing crops can utilize it. A country may have a considerable rainfall, but if it don't come at the time of year when the crops need it, it don't avail much. Of the 3,000,000 square miles of land in the United States, excluding Alaska and the Islands, about 1,300,000 are arid. The rainfall throughout the arid region varies greatly. In Nevada, Western Utah, Southern Arizona and Southeastern California the rainfall is so slight that it varies only from two to ten inches per year. Parts of these sections are almost absolute deserts. New Mexico, Colorado, Wyoming, Montana and Idaho have a higher rainfall, varying from ten to twenty inches. These are the States through which the Rocky Mountains pass. The mountains are always great conservators of moisture and the rainfall is always more abundant in an arid region where the mountains are high enough to condense the moisture by the cold of elevation than is the rainfall in the plains below. It is this moisture which falls as snow and rain on the mountains and vicinity which feeds the streams that furnish the water for irrigation in the arid West. In fact most of the streams on which the irrigation projects depend have their source in the Sierras or Rockies.

Why have we such an abundant rainfall in Western Washington, Oregon and Northwest California and such a deficient precipitation in the arid region between the Sierra Nevada Mountains and the Rockies? The reason is plain. It is not due to the proximity of the warm Japanese current, but there is a continual procession of high pressure and low pressure atmospheric areas across the United States from west to

east. These are the highs and lows of the weather map and are known as anti-cyclonic and cyclonic areas. They have nothing whatever to do with tornados, which are storms of very narrow path but exceedingly great velocity, although they are sometimes confused. In the anti-cyclonic or high pressure area the barometer is high and the cold air is coming down from above just as if through a gigantic funnel and spreads out in all directions with a spiral motion. The diameter of the area may be 1000 miles or over and three or four miles high. In the cyclonic area the barometer is low. It is a low pressure area and the warmer air is rising and the air comes in from all sides to take its place with a whirling motion. You might say the high pressure area pushes the low pressure area ahead of it across the United States. The Weather Bureau, in order to make it plain to the public, have likened them to a series of atmospheric waves traveling across the continent. The high pressure areas might represent the crest of the waves and the low pressure areas the trough. This brief explanation is inserted here because twenty years or more ago the weather was not taught in the public schools, and the average man if he can interpret a weather map carefully has been obliged to give the subject considerable study during his leisure moments. These high pressure areas start in the Pacific and push the air eastward, and as the warm vapor-laden air ascends the Coast Range of mountains it is chilled by the cold of elevation, and Western Washington and Idaho and some of the finest forest areas in the United States have a rainfall of over 100 inches per year. When these same winds cross the Cascade Range or the Sierra Nevada Mountains to the westward they part with more of their moisture either as rain or snow, so that by the time they reach the eastern slope of these mountains the winds are dry winds and don't contain enough moisture for abundant rainfall. Hence Oregon east of the Cascade Mountains is a sage brush and in places a lava desert due to deficient rainfall, while Western Oregon is a magnificent forested area. The principal reason then for the aridity of the West is: the winds have parted with their moisture to the Coast, Cascade and Sierra Nevada and Sierra Madre Mountains.

In the hottest summer months the mountains like the Coast

Range, which are only of average elevation, become warmed by the sun's rays and allow the vapor-laden winds from the Pacific to pass over them without chilling them enough to condense the moisture as rain; so they pass over the mountains, no rain falls, and we have the summer drought of the Pacific Coast. In Southern California no rain falls during May, June, July, August, September and October. But little rain falls then from May to November. Another reason for the scarcity of rains in Middle and Southern California during the summer is (See Year Book of Agriculture, 1902, Wet and Dry Seasons in California, by McAdie,) "few atmospheric pressure areas or disturbances pass eastward from the Pacific over Middle and Southern California during the summer. There seems to be an area of permanent high pressure over the ocean unfavorable for rain bearing winds on the Pacific Coast. During the winter months an area of permanent low pressure overlies the Pacific, resulting in an air circulation such that south, southeast and southwest winds prevail. During this period numerous atmospheric disturbances are experienced in the Northern Pacific and these in their eastern passage cross the coast at any latitude from Sitka to San Francisco, the larger number passing inland north of 45th parallel. The rain for the year falls practically in the months of November, December, January, February and March. Showers in April and early part of May bring the growing crops to fruition. When little rain falls in December, January or February, the outlook is poor for the crops in California."

Leaving California let us consider the arid region as a whole and we will find that there are other reasons to account for the aridity. The principal reason is that conditions are not favorable for the precipitation of moisture in certain desert divisions of the arid region even if the air had moisture enough to produce copious showers. Where there are high mountains in the arid regions the rainfall is much more abundant because as the winds ascend the slopes the air expands and hence its capacity for moisture decreases; then again it is chilled by the cold of elevation. It gets about one degree colder on an average for every 300 feet you ascend a mountain. The expansion and cold serve to condense the moisture in the air and it falls as rain or snow. So we see that in parts of the arid region the

What irrigation will do in southern Arizona deserts. An unusual sight—the giant cactus cereus giganteus or (suguarro of the Mexicans) 40 feet high, growing in a field of alfalfa. This is not in the Yuma region, but in the Salt River Valley.

Laguna dam site

Steam dredger at work, Laguna dam

A driveway on irrigated land near Yuma, Arizona

air may have enough moisture to form rain, but conditions are not favorable for its precipitation and it may happen that heavy showers in a humid region were condensed or precipitated from air that originally traveled over part of the arid region. For example, warm, dry air which is rising from the desert will not condense moisture in the clouds above. The tendency is just the reverse; it tends to dissipate the clouds. Prof. Henry states, (See U. S. Weather Bureau Bulletin D, 1897): "Tables of annual precipitation tell us how much rain or snow falls during the course of the year, but they afford no indication as to whether the rain comes when it will be of the greatest service to agriculture or whether it falls after the time of maturity of the staple crops. The distribution of precipitation throughout the year is fairly uniform in the States along the middle Atlantic, in New England, in the Ohio Valley and along the borders of the Great Lakes. It is strongly concentrated in the summer months upon the Great Plains. On the other hand it shows a pronounced maximum during the winter season in the Great Basin (Nevada), where summer rains are most needed. At Winnemucca, near the center of the Great Basin, the midwinter (January) fall is nearly twelve times that of the midsummer (July) fall, while the Great Plains show a difference between the records of these months in the ratio of about five to one, on the average, the other way. For example, Garden, in Western Kansas, is upon the High Plains; the record is 17.4 inches for the year, of which 14.1 inches are credited to the six months from April to September. It is evident then that rain water in order to be of much benefit must fall during the time of year when the crops are growing. The winter rainfall is not entirely lost, however, as it keeps the soil moist and sinks below the surface to the ground water; then again evaporation is less during winter when the air is cold. In order to conduct agriculture successfully and raise fair crops at least twenty inches of rain per year are required. It may be a little less will suffice if it falls at particular favorable times, but when the rainfall is less than twenty inches per year we cannot raise abundant crops without irrigation. Even trees require for successful growth from twenty to twenty-five inches per year. One curious and interesting fact about climate and rainfall is that on the barren staked plains of Texas (Llano

Estacado) that are so dry that agriculture is almost impossible, the rainfall is as great as in the center of the wheat belt in Dakota. For example an eighteen year record at Amarillo on the staked plains in the Panhandle of Texas shows an annual rainfall of 21.94 inches; this is a grazing region, not agricultural. Yet in the center of the great wheat belt in Dakota at St. Vincent the rainfall is but 19.5. (See 21st U. S. Geological Survey Report, Part IV, page 659.) But this is explained by the fact that the hot dry south winds of Texas take up moisture like a sponge. The days are hotter, the rains spasmodic, so that the water evaporates quickly and does not sink into the soil freely enough. The facts given in this article about rainfall are necessary in a discussion pertaining to irrigation. You cannot separate rainfall and irrigation. The U. S. Geological Survey Reclamation Service state:

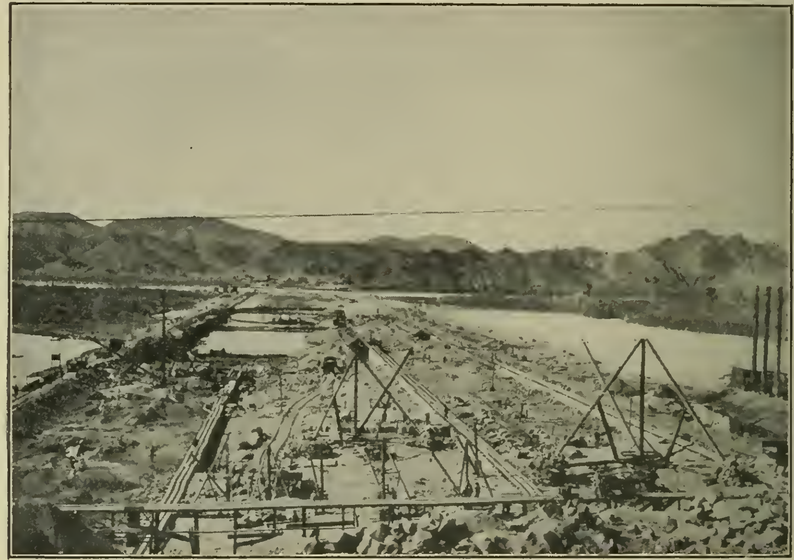
"The following brief statement regarding irrigation projects under consideration and construction by the U. S. Reclamation Service and concerning irrigable lands in public and private ownership, which will eventually be reclaimed by means of proposed system, is published in circular form for convenience in answering inquiries and for the information of the public generally."

Their statement about the Yuma Project reads as follows:

CALIFORNIA: YUMA PROJECT.

"This project contemplates diversion of the waters of Colorado River by means of proposed Laguna dam and sluiceways, about ten miles northeast of Yuma, Arizona, into two canals, one on each side of the river. In Arizona these canals will irrigate all the bottom lands of Colorado and Gila Rivers between the Laguna Dam and the Mexican boundary (an area of 84,000 acres in round numbers), and in California the bottom lands in the Yuma Indian Reservation (an area of 17,000 acres), all tributary to the Southern Pacific Railroad. Plans also contemplate the construction of a complete system of levees to protect the bottom lands from overflow, and a pumping system to remove the surplus water from the low-lying areas. Lands under this project have been withdrawn under the provisions of the reclamation act of June 17th, 1902, from

all forms of entry except by homestead. The mesa lands have been withdrawn from all forms of entry. Under the provisions of this act an individual holding may not exceed 160 acres. Definite decision has not been reached as to the farm-unit area, but it will probably not exceed forty acres to each entryman. The method by which the lands of the Yuma Reservation will be disposed of to settlers has not yet been announced. It is probable, however, that the reservation will be thrown open upon the completion of the irrigation works. The cost of



Laguna dam, 4780 feet long. General view of dam taken from above Arizona sluiceway

the works will be assessed proportionately upon each acre of land reclaimed, to be paid by settlers in ten annual installments without interest. The only additional charge will be for maintenance. The distribution of water, collection of payments, maintenance charges, etc., will be looked after by the Yuma County Water Users' Association, M. Winsor, President, at Yuma, Arizona. The members of this Association are the landowners of the district to be affected. Printed matter and information of a local character regarding the section may be had upon application to Association headquarters, at Yuma, Arizona. On July 6th, 1905, a contract was awarded to J. G.

White & Co., New York, for the construction of the Laguna dam and sluiceways. Excavation is being carried on and other preliminary plans are under way with a view to the construction of the dam. On September 13, 1905, a contract was awarded for the construction of Yuma dikes on which actual work is now under way."

THE COLORADO RIVER.

The Colorado River is the great river of the arid southwest. In an arid region rivers are scarce and generally of small volume on account of deficient rainfall and rapid evaporation, but the Colorado is an exception. One branch of the Colorado River, the Grand River, rises in the Rocky Mountains in the highest peaks of the Park Range in Colorado west of Long's Peak, where it is fed by Alpine lakes and hundreds of brooks formed by the melting of snow. The other branch of the Colorado, the Green River, rises just south of Yellowstone Park, in Wyoming, near Fremont's Peak, on Wind River Mountains, at an elevation of 12,000 feet. These two rivers unite in Utah and form the Colorado, which flows southwest 200 miles, then west for 150 miles, then south 300 miles into the Gulf of California. After leaving Utah it flows through the Grand Cañon in Arizona for a distance of 218 miles. This stupendous cañon is from 4000 to 6500 feet deep and from five to thirteen miles across and is the greatest scenic wonder in the world. The length of this river is 2000 miles. In Utah and Northern Arizona it flows through the plateau country which is from 4000 to 8000 feet above tide. After leaving the Grand Cañon below the mouth of the cañon the river forms the boundary between Arizona and California and flows through a region as absolute desert as the Sahara, almost rainless, and but a few feet above sea level. Near the Gulf its flood plain is ten or more miles in width. If you call the Green River the source of the Colorado and the Grand a tributary, then it has but four principal tributaries, the Grand, San Juan, Colorado Chiquito and Gila, and these are all on the eastern side in marked contrast with hundreds of tributaries on each side of the Mississippi, but we must remember the Colorado flows through an arid region the greater part of its course where the rain fall varies from two to fifteen

inches. It is the melting of the snows and the rains on the mountain tops which furnish most of the water, but they told me at the Grand Cañon that the river would sometimes rise sixty feet in a night after the cloudbursts in the plateau region, and many of us know what cloudbursts mean in the plateau region. Streams of liquid mud six feet deep will flow across the desert which in a few hours will be as dry as punk. The Colorado River drains an area much larger than the New England and Middle States together, an area of over 200,000 square miles, and several writers have called it the American Nile. They have some features in common. The Nile also flows through an arid region and it flows 1000 miles without receiving a branch; it has a flood plain from five to fifteen miles wide. The Nile flows north from Lake Victoria, Nyanza, and the lake basins near the source of the Nile have breakings or faultings of the earth's crust like we see in the plateau region in Arizona.

The Nile would probably dry up before it flowed its long course were it not fed from the humid lake region of Africa. So would the Colorado perhaps during part of the year were it not fed by the snows and rains from the high and humid mountains, because it flows through a Sahara-like region in its lower course. As the rainfall around Yuma is but from two to fifteen inches per year and it has the reputation of being one of the hottest places in the country, the highest official temperature being 118 degrees in the shade, it can be readily understood that irrigation is absolutely necessary if any crops at all are to be raised.

The Gulf of California originally extended 150 miles farther northwest than it does to-day; it extended as far as Indio.

The Colorado is a muddy river and brought down thousands of tons of sediment, the wear and tear of the western part of the continent, produced by erosion. As it poured its waters into the Gulf the velocity was checked and the sediment deposited produced a delta. Even at the present day it is calculated by the Reclamation engineers that the Colorado River in twenty-four hours during a high flood carries past the dam site 1,500,000 tons of silt. In past times this delta traveled southwest across the Gulf and finally isolated the northern portion of the Gulf entirely.

In a region whose torrid heat is almost tropical and where evaporation is exceedingly rapid, an average of at least eight feet per year, this isolated inland sea gradually evaporated and left a large depressed area, most of which is below sea level. The old beach line is plainly visible in the north and is on a level with the Pacific. This area north of the Mexican boundary line is now known as the Imperial Valley. The deepest part of this valley contains the so-called Salton Sink, now called the Salton Sea, and is over 300 feet below sea level. From time to time the Colorado overflowed its banks and de-

Reversed abbatis and screen dike for the protection of the Yuma Valley dike, five miles west of Yuma, Arizona

posited silt rich in plant food over the floor of the valley, so that much of the Imperial Valley contains fertile soil. There were two parallel dry river courses or arroyos which extended from the Colorado River northwest and emptied into Salton Sea. As a rule the high water in the Colorado only overflowed enough to fill these rivers for a short distance from their sources, and it was a rare occasion for the Colorado to overflow sufficiently for its waters to reach the Salton Sea. In 1891 these rivers were not only filled but overflowed their banks and the surrounding country and in some places even united, as they were

but a few miles apart. The Salton Sea rapidly increased in volume.

The report of the Mexican Boundary Commission states "that the channels of these streams are fringed with a thick growth of mesquite while the limits of overflow are plainly marked by a most luxuriant growth of an amaranthus (called quelite by the Mexicans), a plant much esteemed as food for cattle. The growth of quelite, mesquite and grass following the overflow of 1891 furnished a fine pasturage for several thousand head of cattle, brought here from the overstocked ranges of Arizona and California."

This Imperial Valley was practically uninhabited then, but when the settlers saw the abundant forage crop produced by the overflow of the river they reasoned that by diverting the Colorado into canals and irrigating ditches the desert would bloom like a rose. Finally in this desert valley 100,000 acres were irrigated, new towns started connected by branch lines to the Southern Pacific Railroad system. The people poured into this fertile valley almost like the exodus from the settlements into a new mining camp when a rich find is made, until nearly 10,000 people were living below sea level in a valley which was once a trackless desert waste, made fertile by irrigation. One of the canals that the settlers built tapped the Colorado just a short distance below the Mexican boundary line. Of course it was down grade from there to the Imperial Valley. They simply ran the canal into one of the dry streams or arroyos and gave it the name Alamo River. There were no headgates to regulate the flow, so that during a time of flood when the Colorado was unusually high the greater volume of water left its usual river channel and poured its waters into the canal and finally reached the Salton Sea through one of the river courses formerly called Alamo River. This sea is now an immense inland body of water increasing in size. The New River channel also filled and finally these two streams united forming a stream several miles wide flowing into the Salton Sea. The Southern Pacific Railroad tracks have been submerged. At Salton one of the most remarkable and valuable deposits of salt in the United States was ruined by the rising waters. There was a field of salt of 1000 acres where the crust formed from six to sixteen inches thick looking like a great deposit of

snow. It was of unusual purity (95%) and was simply plowed and raked into rows. The salt would soon form again after it was raked from the marsh. The waters of Salton Sea continued rising until the salt fields were submerged. The Southern Pacific tracks were moved twice and finally the telegraph poles were covered. The curious sight of fields of waving sage brush and other desert plants along a shore line of white caps is seen.

The Colorado is still pouring its water into the Salton Sea which is daily rising. The dimensions of this sea at the time of writing (September, 1906,) I am not certain of, but estimate that it is from forty-five to fifty miles long and from fifteen to twenty-five miles wide and perhaps forty to fifty feet deep in the deepest parts that have recently been submerged.

It is absolutely necessary that the Colorado be diverted into its proper channel, otherwise parts of the fertile lands in the Imperial Valley will be submerged permanently. Then again it is not fair to our sister Republic, Mexico, because thousands of fertile acres on the other side of the boundary line will be rendered worthless without irrigation. A dispatch from San Francisco dated August 24th states that the Salton Sea in the Colorado Desert is now rising less than an inch a day and they expect in a few weeks to begin work on a plan by which the Colorado River will be restored to its original channel. This, it is stated, will probably cost the Southern Pacific Railroad $700,000. Heavy embankments are to be built where the river is overflowing into old channels. This will be a tremendous undertaking and an engineering feat of rare skill, as the break in the banks of the Colorado is three-fourths of a mile long. The water of the Salton Sea will soon evaporate when the overflow is stopped.

This description of the Salton Sea and the overflow of the Colorado River are features that could not be omitted from an article on irrigation near Yuma.

The irrigation dam which the Government engineers are building is located twelve miles above Yuma at Laguna. It will not rest on rock because borings did not reach bed rock, which is buried under many feet of silt. The dam, which stretches across the river channel from bank to bank, will have a length of 4780 feet, its height will be but nineteen feet, but

its width up and down stream will be 267 feet. Its contents will be 356,000 cubic yards, the weight about 600,000 tons and the cost about $1,000,000. It will hold back the waters of the Colorado, forming an artificial lake about ten miles long. The dam is of the East India weir design and has been tried at many places in Egypt and India. On the Nile River to-day they are in successful operation and the conditions there are similar to Yuma. The solid masonry rests on sand and silt. For these later facts about the dimensions and construction of the dam, disposition of silt and other details, I am indebted

Reversed abbatis constructed for protection of Yuma Valley dike, about five miles west of Yuma Arizona, showing accumulation of driftwood during one flood. Yuma project, March 31, 1906

to the Reclamation Service and to excellent articles by J. B. Lippincott, Supervising Engineer, (Annual Report Smithsonian Institute, 1904,) and C. J. Blanchard, Statistician of U. S. Reclamation Service, (National Geographic Magazine, February, 1906.)

The engineers explored with the diamond core drills all the sites between Yuma and Picacho for bed rock before the Laguna site was selected. They considered a high dam and a

high line canal out of the question. Mr. Lippincott describes the weir dam as follows:

"This type of weir consists of loose rock structure with a paving of stone two feet in thickness on the down stream slope, the structure being tied together with three parallel walls of concrete run longitudinally between the granite abutments on the two sides of the river, and the entire structure being further made secure by an apron of loose rock pitching ten feet in thickness and fifty feet in width at the lower toe of the dam below the sloping pavement. The height of this weir is to be ten feet above low water and the slope of the down stream side is twelve feet horizontal to one foot vertical, with the fifty foot apron below. The design calls for the upper core wall of concrete to rest upon a row of sheet piling driven into the bed of the river. The handling of the silt he states is one of the most difficult features of this undertaking. It is known that its amount is very large.

"The river is on a grade of approximately one foot to the mile above the Laguna weir site, so that this weir, ten feet high, will make a settling basin of relatively quiet water, approximately ten miles in length above it. At each end of the weir and constructed in solid granite rock will be a sluiceway 400 feet wide on the Arizona side and forty feet wide on the California side, with provision for its enlargement to 200 feet when desired, and excavated to the depth of two feet below low water in the river. These sluiceways will be closed by large gates operated mechanically. The diversion canals will take their water above these gates from the sides of the sluiceways. The area of these sluiceways being so great, the water movement toward the canal will be slow, and most of the sediment will be deposited before reaching the canal intake. When this has accumulated to a considerable extent, the sluice gates will be opened, and it is estimated the flow will be approximately 20,000 cubic feet per second. This great volume of water passing through the sluiceways when the gates are opened will carry out with it the sediment deposited above the intake of the canal. The ordinary low stage flow of the Colorado River is from 3000 to 4000 cubic feet per second; so that the capacity of these sluiceways will be about five times the low

water flow of the river. These figures are given for the purposes of comparison only.

"As the result of a number of experiments it has been found that the principal quantity of silt is carried along near the bottom of the river and that the surface water is relatively free from sediment. It is planned therefore to take the water into the canals by a skimming process over a long row of gates, so that the entire capacity of the canal can be furnished by drawing but one foot in depth of water from the surface of the river. Every portion of this weir and headworks as designed would be of rock concrete or steel with the exception of the sheet pilings, which will be driven entirely below water level and so will not decay. The capacity of these canals at their intake will be 1600 cubic feet per second on the Arizona side and 200 cubic feet per second on the California side. The amount of silt that would be daily delivered into the Arizona canal if diversion were made directly from the stream would approximate 17,000 cubic yards of wet mud by volume. It is not believed to be possible for a canal to continuously operate successfully for the irrigation of lands along the valley of the Colorado River unless some very substantial arrangements are made at the headworks for the handling of silt, and this is believed to be a justification for the expenditure proposed for these headworks; also the water must be held to a fixed level at the canal heading for all stages of the river. This structure will cost approximately $1,000,000. It is not considered possible to remove all of the silt from the water, but the canals have been designed so that the velocities will be sufficient to convey through to the fields the light material entering the canals from the intake.

"One of the most difficult problems in connection with this project is the crossing of the Gila River. It has been considered necessary to make this perfectly safe and for this purpose a structure has been designed that will cross beneath the bed of the river, the top to be several feet below the lowest point of the stream bed. This structure will be of steel and concrete some 3000 feet in length. It will be an inverted syphon consisting of four concrete pipes ten feet in diameter reinforced with steel rods. Because of the annual rise of the Colorado River, a large portion of the lands along this stream are sub-

ject to annual overflow, which practically prevents residence thereon, as well as the farming of them without protective works. The levee therefore is considered an essential feature of the enterprise. The shape of the levee adopted is one that has been developed by years of experience along the Mississippi River. It will have a slope of three feet horizontal to one foot vertical on the water side, and two and one-half feet horizontal to one foot vertical on the land side. It will be eight feet wide on top, and be built five feet above the highest water marks of the year 1903. These levees will be 4000 feet apart (one on each side) along the Colorado River and 3200 feet apart along the Gila River. Because these lands are so flat and the level of the water in the ground so near the surface, it is considered necessary for their permanent safe irrigation to supply a drainage system. A main drainage canal has been designed to run through the central portion of the areas to be irrigated and when possible the natural drainage lines of the country will be utilized, deepening them with a steam dredger to such depth that they will carry off the water returning from irrigation or seepage through the levees during the high water stage of the river. When lands in any district tend to become alkaline they may be connected by means of local drainage canals, with this main drain, and in this manner they could be kept free from alkali by holding down the level of the ground water. During the greater portion of the year when the river is low, this drainage water would be discharged into the stream, but when the river is in flood its elevation will be such as to prevent a discharge into it from the drains. A pumping plant has therefore been designed to lift the drainage waters over the levees during the flood period of the river to prevent the lands becoming water logged.

"The Secretary of the Interior has set aside $3,000,000 of the Reclamation Fund for the construction of this project, contingent upon the action of the landowners of this valley and their entering into contracts with the Department in accordance with the provision of the Reclamation Act, passed June 17th, 1902. On March 15th, 1905, bids for the construction of the dam were opened and responsible bidders offered to build this structure for the amount estimated upon by the engineers."

Too much praise cannot be awarded Mr. F. H. Newell, Chief of the Reclamation Service, and the very able body of engineers under the employ of the Government. One has only to study the water supply and irrigation papers and the annual reports of the U. S. Geological Survey that treat of hydrography to learn of the thousands of painstaking observations that were made before the irrigation projects were planned.

The projects require engineering skill of the highest order. The Roosevelt dam in the Salt River Cañon, Arizona, will be solid masonry 285 feet high, and will join the cañon walls several hundred feet apart and form a lake twenty-five miles long and 200 feet deep. The United States will soon take the lead as the foremost country where irrigation is practiced on a grand scale.

EFFECT OF DURATION OF STRESS ON STRENGTH AND STIFFNESS OF WOOD.

It has been established that a wooden beam which for a short period will sustain safely a certain load, may break eventually if the load remains. For instance, wooden beams have been known to break after fifteen months under a constant load of but 60 per cent of that required to break them in an ordinary short test. There is but little definite and systematic knowledge of the influence of the time element on the behavior of wood under stress.

This relation of the duration of stress to the strength and stiffness of wood is now being studied by the Forest Service at its timber-testing stations at Yale and Purdue Universities. The investigation should determine: the effect of a constant load on strength; the effect of impact load or sudden shock; the effect of different speeds of the testing machine used in the ordinary tests of timber under gradually increasing load; and the effect of long-continued vibration.

To determine the effect of constant load on the strength of wood a special apparatus has been devised by which tests on a series of five beams may be carried on simultaneously. These beams are two and three inches in section and thirty-six inches in length, each under a different load. Their deflections and breaking points are automatically recorded upon a drum which requires thirty days for one rotation. The results of these tests extending over long periods of time may be compared with those on ordinary testing machines, and in this way safe constants, or "dead" loads, for certain timbers may be determined as to breaking strength or limited deflections.

The experiments of the Forest Service show that the effects of impact

and gradually applied loads are different, provided that the stress applied by either method is within the elastic limit of the piece under test. For example, a stick will be bent twice as far without showing loss of elasticity under impact, or when the load is applied by a blow, as it will under the gradually increasing pressure ordinarily used in testing. These experiments are being extended to determine the general relations between strength under impact and gradual loads.

Bending and compression tests to determine the effect of the speed of application of load on the strength and stiffness of wood have already been made at the Yale laboratory. The bending tests were made at speeds of deflection varying from 2.3 inches per minute to 0.0045, and required from twenty seconds to six hours for each test. The woods used were longleaf pine, red spruce, and chestnut, both soaked and kiln-dried. From the results are obtained comparable record for difference in speeds in application of load. A multiplication of the results of any test at any speed by the proper reduction factor, derived from these experiments, will give equivalent values at standard speed. The tests also show concretely the variation of strength due to variations of speed liable to occur during the test itself. The results plotted on cross-section paper give a remarkably even curve as an expression of the relation of strength to speed of application of load, and show much greater strength at the higher speeds. A numerical expression of the law, averaging all species, both wet and kiln-dry, gives the following table, which shows the increase in strength with the increase of speed of tes :

Minutes to move crosshead one inch.	Ratio of ultimate strength Compression.	Bending.
900	100	100
350	100.8	100.9
150	102.3	107.3
40	106.9	110.1
5	113.8	118.7

The first column, which gives the number of minutes required to move the crosshead of the testing machine over the space one inch, is the reciprocal of speed. The second and third columns give the effect of this increase of speed upon compression and bending, respectively, and show that strength increases with speed. The strength at the lowest speed is arbitrarily fixed at 100 as a convenient basis for comparison. The ordinary bending-test speed for small specimens is one-tenth inch per minute, or., reciprocally, 10 minutes are required to move the crosshead one inch.

It is common belief among polemen that the continual vibration, to which telephone poles are subjected, take the life out of the wood and render it brash and weak. Nothing is definitely known as to the truth or falsity of this idea. Tests will be undertaken to determine the effect of constant vibration of the strength of wood. [Trade Bulletin No. 10, Forest Service, U. S. Dept. of Agriculture.]

Book Notices.

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U S. Department of Agriculture, Forest Service, Circular No. 38. Instructions to engineers of timber tests by W. Kendrick Hatt, Ph.D., Chief Engineer, Forest Service. 55 pages, illustrations, 8vo. Washington. Government Printing Office, 1906.

Manchester Steam Users' Association. Memorandum by chief engineer for the year 1905. 51 pages, illustrations, 8vo. Manchester. Association, 1906.

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Scientific Methods in the Study of Handwriting.

In the view I have adopted for treating this theme, by handwriting is meant any symbols, characters, signs, or marks, graven, scratched or stained on any object, by means of which ideas can be conveyed from one living thing to another.

This definition is purposely made broad enough to cover hieroglyphics on stone, writing on papyrus, and even the tramp-like or American Indian-like signs by the mere breaking off of twigs, or the scratching of bark for the purpose of informing or warning some other living being.

You will notice I have put living being instead of man or person, for who can doubt that many of the creatures we regard as lower animals thus communicate with each other? It were hard otherwise to account for their often noticed avoidance of a spot where one of their number has been captured or injured.

You will naturally inquire whether I believe that the "handwriting" which consists in nibbling off blades of grass or break-

ing twigs can leave signs of authorship capable of detection. Although it leads us temporarily away from the real subject I propose to treat to-night I will answer "yes," and the reasons I adduce will furnish a very good introduction to the thesis I shall try to sustain:—

If we regard any physical act of a conscious living being whether human or unhuman, it resolves itself into (1) a picture in the mind of a certain condition of things; (2) the will to make a change in those conditions; (3) the peculiar mechanism by which it must effect this object; (4) the expenditure of the necessary power to produce motion in the mechanism to bring about this change; (5) the guiding of this instrument by intelligence to perform the necessary motions. There are here five elements required to accomplish the simplest act. Not only is this the case but in living beings four of them, the thinking, willing, production of power, and exercise of direction, fluctuate continually during very minute intervals of time, and the instrument itself changes in efficiency though generally more slowly; so that if we had the means of representing each of these elements by a symbol indicating its efficiency (that is its strength or weakness, perfection or imperfection in any act accomplished by the combination of all four), we should almost certainly find one or more and possibly all of these values changed in any repetition of that act.

This change, however slight, would affect their relations to each other and would inevitably cause some change in the result.

If this be true it is a sufficient explanation of the conceded fact that no two things can be made exactly alike. And this is not astonishing when we reflect that these five elements above mentioned represent the conditions due partly to psychical and partly to physical forces, for even when the conditions are purely physical, as in the production of a heap of sand below the narrow tube of an hour glass, or the condensation of a drop of water from moist air on a cool surface, only a sufficiently minute scrutiny is needed to detect differences between any two heaps made in the same hour glass, or any two drops condensed from the same steam on the same surface.

It may then be assumed that no living thing can exactly duplicate any act it may have performed, nor can such exact duplication be obtained by mechanical means; yet each act will

produce in the result characteristics distinguishing it from the acts of all other agents.

Confining ourselves, as the limit of time demands, to marks of human beings conveying intelligible ideas to each other, it seems reasonable to guess that the first of such signs were the simple blazing of trees or the making of marks conveying directions or warnings. And if we may be guided in our belief of the sequence of events in those prehistoric times by that in the period of which we have records, it is probable that hardly were those rude signs invented to guide, before they were perverted to mislead, their ignorant readers, whether enemies or dupes.

So it must have been with the subsequent improvement in conveying ideas through chiseled stone and stained papyrus by imitations of the objects which the paleolithic artist saw around him, and thence on to ideograms having a conventional meaning. Who doubts that the admiring slave, cutting the record of the deeds of his adored Sovereign on the obelisk of Syenian granite added a few more men or birds to his history than the facts justified, and thus inaugurated a system of necrological mendacity which has become a proverb, almost universally illustrated on tombstones even to the present day?

But it was not exclusively pious lying which engaged the ingenuity of early man, but falsification for gain. To suppose that some beneficiary of the generosity of Joseph did not raise the order of the Israelite Governor of Pharoah's granary for corn; or that the architects and contractors of Solomon's Temple did not accept any payment for air and no time; is to make dishonesty too young.

Gradually as the system of life became more complicated the best chiseler, scratcher, or marker would become the head man's scribe, and his records would be more valuable because official. As soon as such a difference of value manifested itself, and there was an advantage in making a record appear to be official, the first forger appeared.

He studied the peculiarities of the official marks and tried to imitate them, and thus obtained more women, cows, or cocoa nuts, than his more ignorant and innocent fellows.

The above sketch of the origin of handwriting and its misuse is purely imaginary though probable, but it is unquestionable that in Thebes, Memphis, Sparta, Athens, Syracuse, and Babylon,

manuscripts were scratched, re-surfaced, and bleached with skill; some passages suppressed and others added, with the result that the writing thus tampered with was either garbled or even frequently made to assert the contrary of its original text. These frauds were, for prudential reasons, usually perpetrated on the works of the dead.

*Eusebius is suspected of having added to the original text of Josephus (who died in the year 95) the oft cited paragraph which confirms certain statements of the Evangelists. St. John himself, by the imprecation appended to his Apocalypse on the head of whomsoever should "take away from the words of the book of this prophecy" (Rev. xxii, 19,) shows how prevalent the crime of forgery was in his day.

Erasmus complained that among all his manuscripts he did not possess a single text which had not been falsified.†

The commerce of falsifying documents begat the art of detecting the falsification, but as in all first attempts to separate the true from the false, and parallel to all previous attempts by man to separate objects into classes, the conclusions were based on merely superficial appearances.

For instance, the great Aristotle's "elements" consisted of fire, water, heat, and cold. All things were fashioned out of them.

In his "History of Animals" he says, "Some animals are aquatic, others live on land * * * Some land animals inhale and exhale air * * * others, like the wasp and bee, do not * * * some obey a leader, others are anarchical * * * the stork and bee are in the first class, the ant, &c., in the latter."

* * * "some animals hunt their food, others not; some are troglodite(lizards and serpents), others not. * * * There are tame and wild. *Man and the mule are in the former class.* (Italics the quoter's.) * * * Some utter a loud cry others are silent. * * * All animals possess in common those parts by which they take in food and those into which they receive it. There is only one sense of touch common to all animals. * * * some have feet, others not. Some winged have feet like eagles and hawks, others like the cockchafer and bee.

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*Of Pamphili of Cæsarea b. 265 A.D. not he of Nicomedia.

†See on this subject "Le faux devant l'histoire &c" Gustave Itasse. Paris,

* * * All which are bloodless (except a few marine cephalopoda) are smaller than those with blood."

"The following are the principal classes: birds, fishes, cetacea;—all these have red blood. There is another class covered with a shell without blood. There are no large classes of other animals."(!)

He and much humbler followers sought to distinguish objects by color and form (changeable), or by habits and cries (often imitated), in other words by purely superficial and trivial features. Yet if a number of these trivial peculiarities co-exist in a single specimen the chance of error is very small. Thus a stout little feathered ovoid with strong short legs, a white speckled breast, a white streaked neck and a short beak, which runs under one's feet with a whirring sound, and pipes from the distant corner of a field or woods "Bob White," may be set down as what is called in Pennsylvania a partridge as certainly as if the anatomist had examined its skeleton and soft parts. But that is only because there are enough separate characteristics to establish identification.

Suppose a sportsman to come upon a dead bird and attempt to name it from its form and color only. If both be normal he probably will not fail; but if, as often happens, one of the elements be not normal; the color and spots absent, or the shape of the bird unusual, he would apply to his friend the ornithologist, who on dissecting the parts would assign the object to its proper genus and species. The case is analogous to the study of handwriting. From the earliest times to the present the determinations have most frequently been based upon the more or less trivial and accidental superficial appearances, and this has made the occupation of handwriting expert the nest of ignorant and unscrupulous charlatans, because unproven opinions were remunerated, and the assertion of an opinion cannot be denied to the most ignorant and venal.

A history of the study of handwriting is not easy to obtain.

In treating the subject of this lecture it is unfortunately unavoidably necessary to pay what must seem exaggerated attention to "experts" past and present because although most of them have never employed scientific methods, they constitute the only class which has dealt with the analysis of handwriting, the

calligraphers, illuminators and writing masters having confined themselves to its construction or synthesis.

Under the general heading of "Psychology" in the Revue Scientifique (Revue Rose. No. 25, 4th Series, Vol. VIII, 18th Dec., 1897, p. 769.) is an article by Alphonse Bertillon on "The comparison of writings and graphic identifications." Over the opening words is a quotation from "Vallain écrivain—juré—expert" to the effect that "One must not neglect too much the proof by comparison of writing nor hold it too slavishly. It is the part of prudence in the judges to give it as much credence as seems good to them."

After extolling the services of the Prefecture of Police in Paris, and his own cleverness in discovering the identity of the false Rabardy, perpetrator of the dynamite explosions in the Rue St. Jacques and St. Martin, with the anarchist who killed himself by the explosion of a bomb on the porch of the Madeleine, M. Bertillon states that in the last century the Lieutenant of Police was President of the Academy of master-sworn-expert-writers, to which no one could belong who had not given a specimen of calligraphy. Still the criticisms of these were much the same as to-day. A certain Raveneau 1656 (whose only predecessor was Damelle in 1609) wrote, says Bertillon. the most complete treatise on the subject up to the present time. He complained of the lack of science of his colleagues which, little or great however, put him into jail for forgery shortly afterwards. Robert Prud'homme (1639), de Bligny (1699), Vallain (1761), d'Autrèpe (1770), and Jumel (1790), are the only authorities he finds in the XVIIIth century.

In the XIXth century he mentions an essay by Saintomer (1832), a little work by Levéque (1840), and a pamphlet (1880) on "The vicious method of expertism in writing" by the Abbé Michon, the founder of "Graphology," concerning which Bertillon remarks, "Here, on the part of the old Abbé, is a method, very questionable and very little Christian, to use occultism for the moral examination of an accused before a court of Justice." Vogt (1880), "Handwriting from the physiological point of view;" Javal, "The mechanism of writing" (1881); A. Binet, "Various very interesting studies published in the bulletin of the laboratory of experimental psychology." Finally he is

good enough to add, "Frazer, United States, 1894. The only scientific work on the subject."

In a MS copy of d'Autrèpe it appears that the Academy of sworn-expert-writers over which he presided kept on hand the best executed forgeries for the purpose of submitting them to the candidates. M. Bertillon concludes that forgeries were much commoner in the past ages than to-day.

Under the existing laws governing these experts in handwriting it is the duty of the first President to inscribe five for the Tribunal of the Seine and all the numerous experts employed by the courts; but this list does not exclude a Magistrate from calling one not thereon inscribed.

Of the experts in, 1897, M. Gobert was formerly a bank clerk and expert chemist; M. Belhomme, formerly of the University; M. Pelletier, a remarkable calligraphist attached to the Ministry of Fine Arts, and M. Varinard, an ingenious adept in Graphology. Besides these are M. Teysonnière, and M. Charavay, archivist and paleograph, both well known. An admirable little book on "Le Faux devant l'Histoire," etc., by Gustave Itasse, appeared in the year following Bertillon's article (De la Grave, Paris, 1898.)

In Germany neither the experts in handwriting nor the critics are wanting. In special branches of the main subject of Bibliotics Germany has furnished, as in so many other branches of applied science, the most valuable contributions. Thus Sittl, of Munich. has contributed important suggestions for determining the fact and the character of alterations in parchments, and the relative ages of parchments and inks; Neumann and Schluttig have given valuable contributions on the manufacture of inks; and there are many others.

Among the sworn judicial handwriting experts W. Langenbruch, of Berlin, who, with the coöperation of Sanitation Counselor, Dr. A. Erlenmeyer, of Bendorf on the Rhine, and Professor Dr. W. Preyer, formerly of Wiesbaden, issued a monthly sheet called "Die Handschrift" (or "Handwriting") from April to December inclusive, 1895, which contained some interesting contributions and illustrations. At the end of the last number, however, appeared the significant notice that at the close of the year 1895 "by mutual agreement of Editor and Publisher its appearance would be discontinued." In the first number occurs a

sharp criticism of M. Bertillon's then newly announced discovery of pulse-beats in handwriting by means of which he was said to have proved Dreyfus to be the author of the bordereau after two experts had declared it, in their opinion, not to have been written by the hand of the now famous artillery Colonel; one declared that he could not form a definite opinion; and the fourth believed Dreyfus to be the author.

The convincing effect of M. Bertillon's argument upon the court induced M. Langenbruch to try the experiment upon several specimens of natural handwriting magnified to eighteen diameters, but "the exact, wearisome experiment upon the projected characters led to an entirely negative result." The magnification of objects for the purpose of judging of their genuineness is most frequently like raising the voice to make a foreigner understand you.

Throughout all the discussions in the journal the assumed foundation for Graphology is everywhere apparent, as is the same assumption of the French experts that there is nothing in any handwriting so characteristic and individual as not to be found in some other. German transcendentalism, or perhaps its supposed origin in Goethe and Lavater, may account for this attitude towards Graphology. It is certainly not indicative of ignorance, for we find Prof. Preyer the author of a considerable work in that year on the "Psychology of Handwriting."*

*(Zur Psychologie des Schreibens etc. Von W. Preyer Hamburg und Leipzig. Verlag von Leopold Voss, 1895), a work full of painstaking observations on the method of producing writing, but also of the mysticism of Graphology. After mentioning the monthly French publication "La Graphologie," the "Histoire de la Graphologie," by Emile de Vars, and the "Traité pratique de graphologie," by Crépieux-Jamin, with approbation, he adds, " * * Germany furnishes only very few original works in this practically and theoretically extraordinarily important department."

Among these he mentions the examinations of Langenbruch, the head of the Graphological Bureau of Berlin.

Dr. August Diehl, of Heidelberg, has published a valuable treatise on the "Peculiarities of the writing of the healthy" (Leipzig. Engelmann. 1899).

German authors whose works on this subject are not highly valued by Preyer are "Die Graphologie" (Schweidland Berlin 1883); "Die Handschrift und ihre charactersistschen Merkmale" (Scholz, Bremen 1885); "Beurtheilung seines Charakters, seiner Anlagen u. s. w. nach der Handschrift" (Schumann, Leipzig. Fischer 1883); "Uber Graphologie" (Machmer, Zürich, 1889;) "Das Handschriftenlesebuch" &c (Henze 1854); and "Die Chirogrammatementie (id 1862).

Messrs. Charles Chabot and F. G. Netherclift were famous English experts in 1871, in which year appeared a monumental volume by the Hon. Edward Twisleton on the comparison of the handwriting of Sir Philip Francis and Junius.

Mr. Hardless fulfils the duty of Government expert for Great Britain's Indian possessions in Bombay at the present time.

Points of View.

Of the principal points of view from which handwriting has been regarded, the oldest is purely physical and concerned with superficial or pictorial features. One of the more modern dates from the Abbé Michon in 1880 and occupies itself exclusively with the interpretation of handwriting into a description of character. As to this latter it has been very recently thoroughly analysed by a master and one of the founders of psychological experimentation, Dr. Alfred Binet, Director of the Laboratory of Psychological Research in the Sorbonne, who is a friendly investigator. We owe to him "The philosophy of reasoning," "Experimental researches in hypnotism" (1886), and many late valuable studies. It would take too long to explain here his methods, for which the student is referred to his "Révélations de l'écriture d'aprés un controle scientifique," or to a review of this book published in "Science" of October 5th last. Suffice it to say that selecting the best graphologists in France, among whom M. Crépieux-Jamin is incontestably the foremost, he subjected them to a series of tests in determining from writings unknown to them the sex, age, intelligence, and character of the writers. While testing the professional graphologists he submitted the tests to persons both intelligent and unintelligent but entirely ignorant of the alleged new art. Of course the greatest ingenuity and care were taken to avoid the vitiation of results by what Dr. Binet calls "that cholera of psychology—suggestion."

In determining sex from writing the best graphologist made 21 p.c. of errors. and four instructors and instructresses in the schools entirely ignorant of graphology but 27 p.c.

In determining age the best graphologist's determinations were only about 5 p.c. better than if his answers had been dependent on the tossing of a coin.

In determining intelligence Dr. Binet submitted to each graphologist two writings, one of a distinguished thinker and the other of a man of very moderate intelligence. One graphologist

determined the great mathematician Bertrand from his writing to be "destitute of a clear view of things." Dumas, the world famous chemist, was described as having "mediocre intelligence." Brown-Séquard, "intelligence below the average." Rénan, "moderate intelligence but little cultivated."(!) Even Crépieux-Jamin rated Rénan as a "fine mind without attaining talent." But the most ludicrous results were reached in the efforts of the graphologists to read character in handwriting. The handwriting and complete history of each of a number of vile murderers was secured.

The first of these was an assassin whose practice was to waylay and murder women for the few pennies they had on their persons.

(The picture of this depraved wretch, Vidal, reproduced from Dr. Binet's book to illustrate his graphologically given character, was thrown on the screen. His features were coarsely masculine and brutal.)

This is what M. Vié, the second graphologist in France, has to say of Vidal's character judged by his writing:

"The writing is of a young girl of temperate character. She is not sentimental, though capable of affection and altruism, but controls her emotions. * * * Her principal desire to please is natural to her elevated tastes. * * * She does not exaggerate modesty. She is timid because her lack of impulse does not permit her frankness to follow its natural course. Moderation is her motto. * * * She has imagination not without grace. Most surprising is it that her intelligence, diffuse in most young girls, is distinguished by concise and very condensed sobriety," &c.

Another distinguished expert, M. Eloy, who hits upon the right sex, says of the same murderer: "He is nervous & susceptible. His effort to mask this shows tenderness of heart. * * * He is delicate * * * very young * * * and of a sensitive nature!" Here follows from M. Eloy a passage which must have been especially pleasing to the experimenter—Dr. Binet.

"I have felt almost from the beginning," he writes to Dr. Binet, "that this writing was by M. Binet at the age of 15 to 18. Is this the fact?"

The next murderer, Carron, killed his mother to steal her few francs and jested of her death-agony before the magistrate.

(His picture, also photographed from Dr. Binet's book, was thrown upon the screen.)

M. Vié says of this writing: "Young & feminine, a young girl wrote it. * * * She is pleasantly airy. * * * Gentle, modest, and not coquettish. * * * Of loving nature she possesses a guarded affection. * * * Her moderated imagination does not rest on the blue clouds in which the dreams of young girls delight. * * * She is tenacious of truth, and very apt to attach herself to an object if it come to her." * * *

These are merely a few of the most grotesque failures. In many cases the answers were of a kind which Dr. Binet called a "passe partout;" Delphic utterances ingeniously framed to suit any case, with greatest emphasis on points which cannot be determined.

Without attempting to predict what may be the future of graphology, it may be said that at present it has no greater claim to the title of a science or an art than has astrology, according to the results of this very thorough examination by a friendly investigator.

Scientific Methods.

As yet the application of scientific methods to the study of handwriting has not been mentioned. These may be of two kinds, the one simply intended to furnish information on one or more points of a particular case, and the other to supply a basis for a systematic analysis of handwriting. The instances of the first use of science are innumerable and have been made in nearly every case where a scientific man has been asked to aid in an investigation of this sort. The second kind of application is experimental psychology pure and simple.

It has been stated that from the earliest times the methods used by connoisseurs in judging of works of art were employed by handwriting experts. The expert looking at the genuine and a suspected piece of handwriting; comparing them; holding them at a distance; bringing them close to the eyes; inclining the head first to one side and then to the other; used to say that in his opinion they were or were not by the same hand; and if pressed for a reason gave it as "an indefinable something."

Later the examiners compared the minute details of characters and found bases for their decisions on the curls, crossings, dots, and shadings, etc.

During the last century many questions as to authenticity were settled by applications of science and common sense.

Special application of scientific methods.

Thus in the sixties of the last century there was a will purporting to be signed by Sylvia Ann Howland which was examined by Professor Benjamin Peirce, of Harvard, perhaps the greatest mathematician this country has ever produced. He measured the geometrical positions of 30 downstrokes in 42 unquestioned signatures and found 5325 coincidences of position in two signatures out of 25830 comparisons, say 1 in 5. Comparing the two disputed signatures with one genuine he found all the 30 downstrokes coincided.

By the calculus of probabilities he deduced the chance of these 30 coincidences occurring simultaneously to be one in 2,666,000,000,000,000,000,000 times. Of this result he said: "This number far transcends human experience. So vast an improbability is practically an impossibility, less than those least things which the law cares not for." * * *

"The coincidence must have had its origin in an intention to produce it: i. e. it was a forgery by tracing."

Some five years ago an alleged will of four pages, each bearing a signature, was submitted to examination. As the measurements coincided the four signatures were photographed on separate gelatine films and will here be exhibited on the screen, first separately and then superposed.

(Photographs of four signatures on the four pages of a certain will, and photographs of these when superposed were shown.)

My friend Prof. Hallett of the University of Pennsylvania applied the calculus of probabilities to the exact correspondence of three out of the four dots over the "i" in the last name when the four signatures on transparent films were superposed, without considering at all the equally exact correspondence of many other important parts of the four signatures, which would have increased his denominator by several millions.

Dividing the field into a checker board of squares each as large as the diameter of the dots he found that the probability of coincidence of the three dots was $(21 \times 15)^3 = 1 \div 31,255,875$.

To get a conception of this number suppose a signature to be written every 15 seconds (or four signatures a minute) : then the time necessary to arrive at this coincidence, writing day and night without intermission would be 148.6 years.

Another application of common sense to the detection of forgery was made by Sittl, of Münich, who found on the paper of a document dated 1868 a water mark representing the eagle of the present German Empire which did not come into being until after the war with France in 1870.

Another such application of common scientific sense happened during the famous trial of the Whitaker Will in this city. A will presented for probate at Mr. Whitaker's death in 1878 professed to have been written in 1875, and the ink marks were of that rusty brown color which is frequently noticed in writings of that age and over, due to the oxidation of the iron which is an important ingredient of ordinary inks. The best imitation of this color is a pigment or paint never used for a writing fluid, which contains practically no iron. It occurred to the chemist who first saw the paper that a test for iron in the written characters of the will would show whether the change of color was natural or merely imitated, and it proved to be the latter.

Dr. Chas. A. Doremus showed by a fluoresence test that a writing dated in 1862 was written with Eosine ink, and as Eosine was not discovered till eight years afterwards, the writing was necessarily a forgery.

Similarly an examination of writings by transmitted light and photographs of them show markings and differences between the parts which are not visible to the naked eye.

Dr. Stéphane Minovici, Professor at the University of Bucarest and chemico-legal expert, in a paper read before the 4th International Congress of Applied Chemistry, held in Paris, July 25, 1900, has collected together a number of cases where photography has aided in the detection of, or satisfactorily demonstrated falsifications of writings.

Colorimeter.

Another device for determining questions which may be of

value in an investigation is a colorimeter for fixing what is called the color value of inks. No ink is really black and most inks are distinctly mixed with some coloring matter, usually blue, but almost all inks show more or less yellow and red also. Let us for simplicity consider white light to be composed of red, yellow, and blue rays.

When a fluid ink is traced upon paper it evaporates and leaves on the surface an extremely thin layer of colored material which it previously held in solution. White light falls upon this film and in traversing it loses a very small part of its constituent rays by absorption. Thus the substance in the ink which appears to our eyes blue does so because it absorbs more of the red and yellow rays, allowing proportionately more of the blue ray to escape: the yellow constituent absorbs the blue and red rays most completely and allows more yellow to escape; and similarly the blue ray absorbs the red and yellow.

In ordinary illumination the light traverses the film twice, once in its downward path to the paper, and when reflected from the underlying paper, again through the ink film to the eye. It suffers two absorptions and reaches the eye deprived of a very small part of the rays of the original beam. But this very small loss unless divided equally between the three rays will disturb the balance of colors and the light which reaches us will be reddish, yellowish, or bluish, if the disturbance be sufficient to affect the sight. In ordinary cases it is not sufficient and some artificial device is necessary to ascertain the change which has taken place.

For this purpose I have used three small prisms of red, yellow, and blue glass respectively. If in turn the thin edge of each of these prisms be placed over an absolutely black line, by pushing the thick end towards the line the whole field of the paper, colored by the particular prism used, will grow darker the greater the thickness, but the line cannot grow darker if it be, as supposed, absolutely black from the first. In this case the color value of the ink would be Red 0, Yellow 0, Blue 0.

But if the line to be measured emit the least trace of color—say yellow, the conditions will be changed. When the red and the blue prisms, both of which absorb yellow light, are passed successively over the line the latter will be observed to darken, up to a certain point which may be read on a scale underneath. If

the prism edge be pushed beyond this point the whole field of view darkens equally with the line simply because the greater thickness of glass at the base of the wedge or prism is cutting off more light. At the point where the line ceases to grow dark more rapidly than the field on which it appears, the number of units of the scale is read off and noted as an empirical red color-value for the ink. The same process being applied by the aid of the yellow, and blue prisms, the empirical color-value of the ink for a given illumination is noted: Say as R—7, Y—35, B—11.

Another ink line being subjected to the same examination if the values agree closely one may conclude from the physical to the chemical similarity of the inks with a very high degree of probability. If the proportion of color-values disagree it may be safely assumed that the physical and therefore the chemical constitution is different. In fact without in any way injuring the writing, the test gives as much information of value in determining agreements or differences, as a chemical test.*

(Measurements of lines drawn on glass with standard inks were made on the screen by projecting a millimeter scale under them and passing the colored prisms across the field.)

Another useful device for determining which of two lines is above and which beneath depends upon the fact that when light falls upon a surface at a very acute angle it is totally reflected and reveals the true outline of the surface of a mark on which it falls, no matter how transparent the film composing that mark may be.

If a very black ink line underlie a very pale one it will be impossible by looking down on it to determine which of the two is uppermost. But when illuminated by light falling very obliquely to the surface the order in which the lines have been traced becomes perfectly apparent.

(This was shown by an experiment with two strips of differently colored glass bound together at their intersection and obliquely illuminated by the lantern beam.)

The extent to which the writing of one person may be modified by another grasping the same pen is an extremely interesting study. I have published papers on this subject in the Proc. Am.

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*The City of Philadelphia awarded the John Scott medal to the deviser of this colorimeter.

Phil. Soc. and elsewhere, but it would take too much time to discuss the subject here. From the results of experiments undertaken it is by no means impossible that a minute examination of such joint writing may frequently suggest the two persons concerned in making it.

But a simple case of joint marks is given in two photographs on the screen. (Fig. 1.) It was claimed that in both cases the hand of the person whose mark was being made touched the pen handle while another person made the mark. 3500 crosses were made and studied under the microscope by me without finding a

Fig. 1. The upper cross was made without the touch of a second hand on the pen holder. In the lower figure the pen holder was touched by another hand.

single exception to the rule that one or both margins of the line so made were crooked and irregular, and one margin continuously so.

A very interesting study of the effect of rotating a pencil in the hand to supply a fresh point when the first point is abraded, and the different directions of rotation employed by different writers is illustrated on the screen. The words "J. L. Morton, Boston, Mass.," were found written on a piece of paper without further mark.

The pencil writing of a person suspected of being the writer of

these words was examined under the microscope, and tracings of parts of the pencil line of each were made, and are shown on the screen. (Fig. 2.) A surface of paper is not really smooth as it seems to be, but is composed of fibres which stand up somewhat as the stalks of grain in a wheat field, and this is the most evident the less the amount of sizing or surfacing has been used. When a pencil point commences to write it is soon abraded to a flat sur-

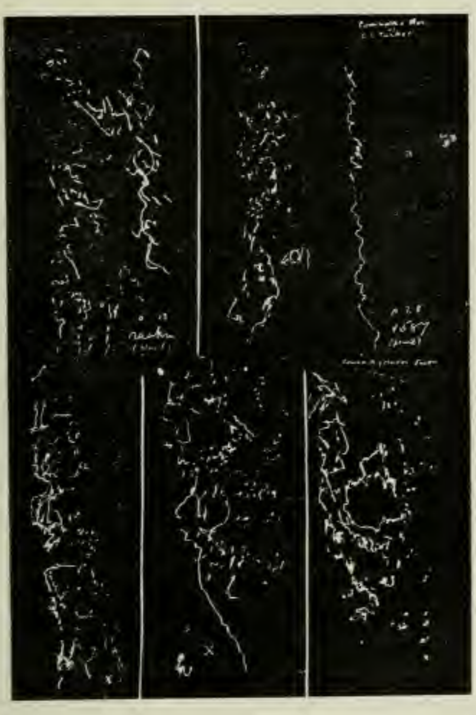


Fig. 2. Partial tracings of pencil marks made by two persons. In the two upper marks the writer rotated the pencil to the right as is shown by the fragmentary character of the left hand margin of each of the two magnified pencil lines. In the three magnified marks below the fragmentary character is on the right hand side showing that the rotation was to the left.

face which makes a broad and indistinct line. Instinctively writers turn it, some to the right and some to the left, to use the edge or point which has been newly made. In turning it the plane surface extends up from the paper obliquely and smudges the little standing fibres near the line of writing, but this effect becomes less as the distance on the paper from and perpendicular to the line increases, until only a few scattered fibres have their

tops blackened. The side on which this archipelago appearance occurs will depend upon which way the pencil has been rotated. In the writing in question it was on one side and in that of the suspected person on the other.

A decalcomania or composite putting together of letters taken from the writing of this suspected person to form the words J. L. Morton, &c., furnished additional proof that he had not written it.

Application of scientific method to the entire subject of the study of handwriting. Bibliotics.

But all these cases are of individual application. They are tests to determine yes or no as to a single question which may or not be sufficient to prove tampering or alteration. Every case of any kind must offer opportunities for this sort of exercise of common sense. Every man who walks the street does so presumably with sufficient intelligence to enable him to surmount a coal chute which may bar his way and which he may never have met before or since. Exercise of this kind of intelligence does not approach the subject of the scientific study of handwriting.

Twenty-five odd years ago before the science of psychology had established itself as one of the galaxy of anthropological researches; and before experimental psychology existed. I was led to begin the study of handwriting by methods which are now recognized as those of experimental psychology.

Starting with the observation that many of the concrete results of man's acts reveal their author by appearances due to peculiarities of constitution of his mind or his body let us suppose a person wishes to write a capital "A." He has long before selected the model which he prefers for this letter, and the method of producing this model on paper. Before he makes the first mark he has decided how large the letter shall be. (I mention this because it is unquestionable that the space available, and many other trivial and variable circumstances influence a writer to write larger or smaller letters than his average, and this fact, together with an inherent sense of proportion of one part to another, furnishes an excellent means of detecting authorship as I shall show later).

To accomplish the simplest stroke the person supposed has, first, a mind with functions peculiar to itself, in which the image

of what he is going to attempt is impressed. He has to materialise this model by means of a wonderfully constructed machine consisting of bone levers, tendon joints, and muscle motors, the latter so moving the rigid parts as to make, as nearly as possible, the tracing desired. But no joints are so perfectly fashioned as to work equally well in all directions. In some of the motions necessary to reproduce the design there will be a less flexibility of the instrument than in others, so that some of the many kinds of strokes necessary will be accomplished in a way differing from the normal of the majority of writers. The same is true of the model in the person's mind, even if that model be the image of a design before the eyes, for two pairs of eyes see the same thing differently; and all these circumstances will influence the resulting tracing.

There are in all writings by the same person two features invariably present; the one a constant tendency to reproduce original forms which have become a habit, differing from the forms of other writers and therefore individual characteristics; the other, a modification or omission of one or more of these (usually numerous) characteristics in any given word or letter. These two features are quite analogous to the two biological "laws" which govern the production of plants and animals, called by Darwin those of "heredity" and of "accidental variation." It is therefore indisputable that the best means of identifying the author of a handwriting is to discover what are the constitutional divergences of his handwriting from the usual forms of ordinary handwriting, and to separate these constitutional divergences from the casual variations from them which exist in every specimen from his pen. The surest and most obvious way to do this is to secure from a number of specimens of his writings the average formation of each of the characteristic features.

This may be done in various ways, as I shall later explain, and when accomplished, the sporadic changes from his usual style will be eliminated, and a type secured containing all, or at least most, of his characteristics.

First of all in deciding questions of authorship the need of a standard as perfect as possible is apparent.

Composites.

In 1881 Francis Galton had read a paper before the Photo-

graphic Society of Great Britain, and shortly afterwards published his "Human Faculty" in which the marvelous results in graphic averages representing types, are shown in families, in professions, in disease, and in crime, by composite photographs. For the methods to be employed consult the book just mentioned.

Fig. 3 is a composite of a father, mother, two sons and a daughter.

Fig. 3. Composite of a family of five, two adults and three children.

It occurred to me in the early eighties to apply the principle of composite photography to signatures and thus obtain a type—*the* type—which the writer had always tried to achieve without quite succeeding, by which the doubtful signature could be judged. The composite I produced was a very clumsy result compared to subsequent efforts.

(Various composites of signatures, including that of Clark & Co., the first ever made, were thrown on the screen. Those who are interested will find many examples in "Bibliotics" or "The Study of Documents.")

Measurement, Average, and Ratio.

But as the problems multiplied I found that not all were susceptible of the treatment by composite photography; sometimes because the standards were in large ledgers, or were otherwise difficult to photograph; sometimes because there was not time to prepare the plates. Besides, when the composite was obtained it was only a means to an end, not the end itself. In other words

the task remained of beginning the work of determining genuineness after the composite was secured.

To meet his need I devised the plan of exact measurements of lengths of word, and groups of letters; heights of certain letters in the words; and the calculation of the ratio to each other of these two latter factors. Without knowing it I had invaded the domain which is now that of experimental psychology by using as a method of detection what proves to be an involuntary habit of an intelligent writer, viz: that of enlarging or reducing all parts of a signature to which the writer is accustomed, with much greater approach to exact proportional relation to each other than any other writer can do this even though he be an expert penman and use his best skill. It will often occur that owing to more space to be filled, or less space available, the writer will change the average length of his signature. In doing so he will inevitably reduce the vertical parts of the writing in close proportional conformity to the lengths—whether from an unconscious measure of the relative amount of time employed in tracing each part, or for some other reason does not here matter.

But the result is that very large and very small signatures when "ratioed" become comparable.

A copier of such a signature has not the same apparatus with which to write it, and is entirely ignorant (as indeed the genuine writer may be) of the rhythm, of the allowance of time to accomplishment, which keeps all parts proportional in size. Consequently the simulator will have some parts right and others entirely discordant with them.

An investigation of this kind applied to the writing of Sir Philip Francis and to that of Junius was published by me in 1901; the word "more" being taken (Bibliotics 3d Ed. 1901, p. 146). While the average lengths of this word in 36 instances of Sir Philip and of Junius respectively were as 22.06 to 14.29, or differed about as 3 to 2 (more correctly by 35 p.c.) the ratios of the length to the height of the word written by Sir Philip agreed within 1 p.c. of the same ratio of the same word as written by Junius.

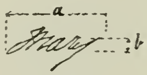
In a more recent study where five genuine and twenty-four disputed words "Mary" and "will" were compared; though the greatest discrepancies existed in actual sizes of the separate words, the ratios of the heights of the letters "r" and "l" to the

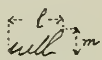
lengths of the respective words of the averages in the two groups of each word differed by less than 1.04, and 0.02 p.c. respectively. (Figs. 4 and 5.)

In the last two instances (Figs. 6 and 7) a part or the whole of one dimension is composed of a gap, a sort of graphic cæsura, where the pen leaves the paper while the motion of the hand is continued, the pen point being carried through the air for a certain length of time before it is again touched to the paper to continue the record.

Study of two words to decide authorship
by the method of
Measurement, Average, and Ratio
Unit of measure $\frac{1}{40}$ Inch

A,X/A July 1906

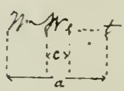




	a	b	$\frac{b}{a}$
Mean of 5 Genuine	53.6	7.7	0.1445
Difference per cent			1.04
Mean of 35 unknown	45.2	6.6	0.1460

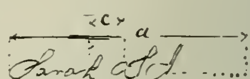
	l	m	$\frac{m}{l}$
Mean of 5 Genuine	30.2	14.8	0.4889
Difference per cent			0.02
Mean of 35 unknown	23.5	11.5	0.4893

Fig. 4 Fig. 5
Comparison of height to length ratios in two groups of words.



	Millimeters a	Millimeters c	Ratio $\frac{a}{c}$
Signature in question	30	6.5	4.61
Per cent Difference			2.33
Average of 13 Genuine	28.36	6.–	4.72

Fig. 6. Ratio of length of word to extent of gap in a signature compared with the ratio in an average of thirteen others.



[redacted]	Millimeters a	Millimeters c	Ratio $\frac{a}{c}$
Signature in question	72	10–	7.2
Per Cent Difference			5
Average of 10 Genuine	71–	9.36	7.5

Fig. 7. Comparison of ratio of length of word to width of gap of a signature with the same ratio in ten others.

The extent of this gap and the relative direction of the point of resumption from the point of departure are extremely characteristic of a writer.

The width of the gap is a distance measured by the writer through that imperfectly understood method of measuring time which we all possess, often ascribed to pulse beats: because with the hand in motion the width of the gap will depend on the time the pen is suspended above the paper. Every one will have his

own peculiar intuition of the time to be allowed in order to produce the effect he intends, and every one's appreciation of the necessary time as well as every one's model must differ from those of others.

But that is not all. The word has been mentally cast to fill a certain space; if this space be the normal average of the writer, then the average obtained from a number of such words written by him will give the extent of this discontinuity very closely, but if he has concluded to write the whole word larger or smaller, the dimensions of the gap must be increased or diminished to fill accurately its proportional part of the word.

From a number of experiments, not sufficient however to establish moduli of rapidity for all writers, I have found the pen point to move 17 mm per second in the slowest and 60 mm in the fastest writing I have timed. Illiterate and phenomenal writers would extend the limits downward and upward respectively.

As a result of all this the occurrence of gaps in a line of writing becomes an extremely important and delicate test of identity of authorship.

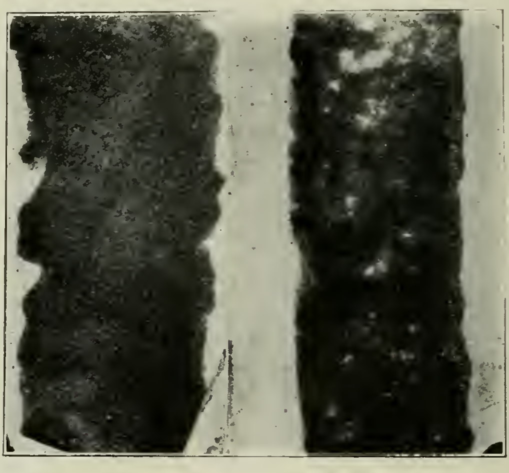
Dr. August Diehl in the very valuable treatise mentioned before on the writing of the healthy, gives tables in which are recorded the lengths of path traversed by the pen in writing the same word on successive trials, and the rapidity of the pen in millimeters to hundredths of a second. He experimented with three writers first writing slowly and carefully, and later fast and without care, on different days and under varying conditions.

His results show that in making a single numeral "8" the path of the pen varied from 11.61 mm. to 13.8 mm., and the rapidity of writing varied from 28.17 mm. per second by the fastest writer of these three persons to 18.76 mm. per second by the slowest. The mean was 23.36 mm. per second. Dr. Diehl (who sent me this book with a very pleasant letter) did not attempt to ascertain the average speed of a large number of writers. The persons upon whom he experimented were four male and four female assistants in the University clinic for the insane at Heidelberg.

There is therefore no discrepancy between his results and mine, but both are insufficient to establish a time average for the writing community.

Tremograms.

Of the same character is a study which is merely begun; that of the curious marginal irregularities which accompany and seem to a certain degree to characterize the handwriting of each writer, which I have called "tremograms." In studying those of different individuals it will be observed that these irregularities differ, (1) in general appearance; (2) in the margin of the ink line on which the greater number of them occur; (3) in the number of these to a unit of length in the ink line; (4) in the rapidity with which lines joining the apexes of the angles on the two margins oscillate up and down from horizontality in a given length of ink line. A few examples are given.



a Fig. 8 b

a—ink line made by hand, here magnified about 60 diameters.
b—ink line made by a ruling machine, here magnified 91 diameters. By an error in printing both these figures have the left and right sides transposed.

In the first illustration (Fig. 8) are represented side by side a line drawn on paper by a ruling machine (b) and a portion of a letter written by Prof. Lightner Witmer (a). The machine drawn line is magnified ninety-one diameters and the hand written line about sixty, yet the irregularities on the margins are less on the former than on the latter. By an error in producing the plates the right and left sides of each of these figures are reversed.

The study of Washington's tremograms is from a letter in my possession which he wrote to an ancestor of mine. The ink is

faded in places but in the parts of the "G" represented, age has only accentuated without destroying the tremograms. (Fig. 9.)

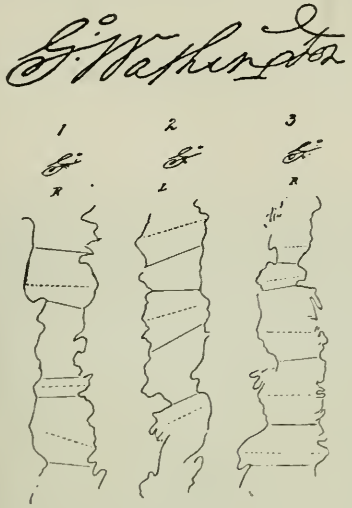


Fig. 9. Three tremograms from the "G" in the above signature. The oscillation of the lines joining the cusps and sinuses from the top to the bottom are observable.

Fig. 10 represents the margins of the ink line as they appear to the eye through the microscope except that the color of ink and paper are reversed. Ordinarily I have used only line tracings of the margins or sides of the ink lines, but I was surprised when an un-

Fig. 10

usually intelligent Assistant District Attorney confessed to me once that he had never clearly understood the tracings until he saw them represented in this way. The marginal tremograms are traced on thick paper and subsequently cut out by a pen knife.

Fig. 11 represents tremograms of two signatures of the same name, to all appearance both genuine. The upper three pairs of margins were from the genuine, the lower two pairs from the

Fig. 11. Tremograms from two signatures pronounced genuine by ordinary tests. The tremograms show them to be by different hands and the lower is a forgery.

forged signature. It was of importance to determine immediately whether or not they were both by the same hand. If not, the forger, who was on his way to the railway station under surveillance, could be arrested. Ordinary tests were unavailing. The two tracings under the microscope here photographed established entirely different characters in the structure of the lines. The culprit was arrested, convicted, and, I believe, confessed.

Fig. 12. This case is a still stronger confirmation of the

value of this method. R's signature had been forged by three conspirators, P, J, and M. The tremograms served to assign to each his share in the transaction. In the case of M he had not been suspected until this test was applied. Subsequently he

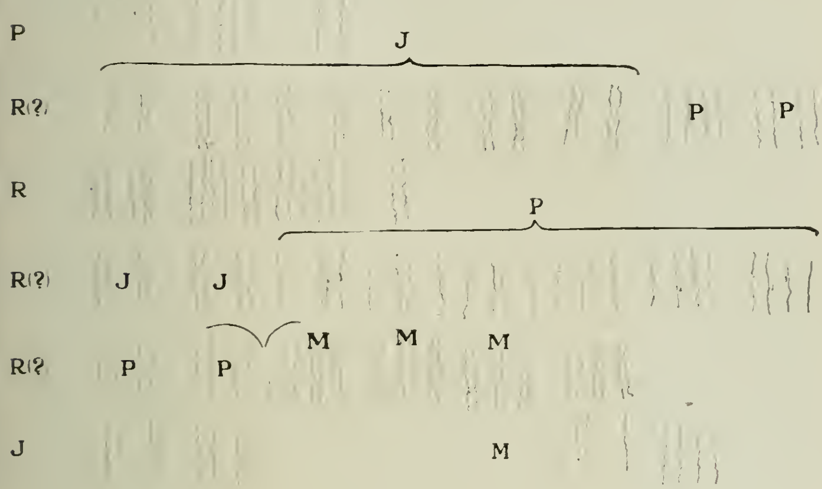


Fig. 12

The above diagram represents the margins of magnified ink lines.

The uneven margins (or tremograms) following the initial letters P, R, & J, respectively, in the left hand vertical column of letters, and those following M on the lower line farther to the right, were drawn from writings unquestionably made by the persons for whom these letters stand.

The tremograms following each of the three symbols, "R (?)," in the left hand vertical column, were made from writings falsely purporting to have been made by R.

The twelve pairs of margins in the second line, under the bracket surmounted by "J," were from writings purporting to have been by R but actually done by J.

The four pairs to the right on this same line were from writings purporting to have been made by R but which really were by P. The four pairs of margins on the fourth line following the second "R (?)" were traced from writings alleged to be by R but which were actually by J; and the twelve following pairs on the same line were from writing pretending to have been made by R but in fact made by P.

In the third line headed by "R ?" (or the fifth line in all) the first four pairs of margins presented as the work of R were from writing produced by P, and the succeeding twelve pairs by M.

Unfortunately the scale is too small to enable one to recognise the analogies of structure of the lines from the same hand between the tremograms of the standards, and those of the simulations of R's writing, especially those by J and M.

The P lines are extremely broad showing heavy pressure on the pen, and very few serrations on either margin. The tremors most noticeable are the smallest, which may be largely due to the constant terrestrial vibrations. It is also difficult to say which margin have the most of these tremors.

In M, on the other hand, and in less degree in J, the tremors are frequent and show sudden changes of direction, but whereas in M the majority of the serrations are on the right side, in J they are about evenly distributed. Perhaps the most sinuous of all the margins are the tremograms of the standard of R, whose writing was simulated by P, J, & M. But these tremors are more serpentine than jagged; and in this, if one might assign nerve action as their cause, we observe what might be expected from the age and debility of the writer.

The last three pairs on the next to the last line (the R ?) should be designated M.

was arrested. The tremograms obtained from authentic writings of R, P, J, and M respectively are placed after those letters.

The tremograms after R(?) are taken from the forgeries of R's name, and in or over each of them is the letter denoting the forger.

Use of the study.

If we concede that the study of this branch of experimental psychology may enable one to detect and chart the peculiarities of handwriting of an individual to the extent of distinguishing the writer by means of it from all the rest of the world's inhabitants —a point far from being attained yet—of what value is this to mankind?

A natural reply would be to protect the dead and absent from being misrepresented by writings falsely ascribed to them.

"It would be invaluable in courts of law" some optimist will exclaim. Vain thought! Forgeries of wills and of certificates of value are plenty enough, but it is rarely that the results of a strictly scientific examination are allowed to be fairly presented to the jury. On the other hand perversions of facts by charlatans and sciolists are seldom excluded, however grotesque or contrary to human experience or the laws of nature they may be.

Thus a learned Judge once refused to recognize the value of a fact vital to the truth or falsity of a cause at issue because the concrete evidence of it was so small that it could only be seen by the microscope.

An unscrupulous pretender once informed a court and jury in my hearing that strong sulphuric acid having blackened a surface of paper with which it came in contact "the color afterwards faded."

It is not lawyers who are most responsible for degrading expert testimony on handwriting; they wish to win their cases and are frequently not quite so particular about the means as the members of the old bar are said to have been. But it is the Judges who are most to blame. Some of them from ignorance of the difference between scientific methods and quackery: others from a disbelief that any one can be entirely uninfluenced in his conclusion in a case affecting the man who pays his fee. These judges are themselves (presumably) chosen for their positions because they are experts in the law, and would visit condign punishment upon a plain citizen who accused them of soiling their judicial ermine by deciding cases in favor of the side best able to promote their advancement. Yet they not infrequently join in the hue and cry against other experts, and very particularly those in handwriting.

It is a fact that expertism in handwriting has been one of a

number of refuges of humbugs and perjurers for hire from the earliest times, and is so today, but even the bench is not entirely free from the same class. No efforts of handwriting experts as citizens could appreciably raise the standard of the Judges, but the latter might easily raise the standard of the handwriting experts by punishing those who are caught in flagrant crime, and more still by according respectful treatment, and protecting from wanton insult by bench and bar, those who have not forfeited the right to be held honest and competent.

The most superficial consideration of the subject will convince anyone that with the advancing complexity of civilization experts in Courts of Law must ever be more and more a necessity. The only alternative to their employment is for Court and jury to be informed on all subjects. This being impossible, and experts on handwriting being as necessary as any others, the wisest course to pursue is to weed out the ignorant and venal. After all, the injury any physical expert can do is slight compared to that which may be done by the lawyer experts, for the testimony of the former affects, usually, but a part of the case, and may be offset, whether true or not, by counter testimony and partisan cross-examination. But the expert lawyer, by his incompetency, may wreck the entire case of his client; and the expert Judge may do that, and make a vicious precedent besides to injuriously affect future cases; and the expert Supreme Judges may so offend the sense of justice of an outraged community that only a revolution with bloodshed can right the wrong.

The United States of America, unsurpassed in so many things, is unsurpassed in miscarriages of justice. There have always and everywhere existed some venal and unscrupulous individuals in every occupation, but events during the last few years hint at the possibility of the existence of organised expert perjury at the service of all malefactors, and, able to thwart justice by the most puerile and absurd contentions through an influence hard to comprehend. In connection with this bureau (if it be one) is a systematized subornation of misrepresentation and garbling at the very source of the syndicated news, so that in every morning paper from Maine to Georgia, and New York to San Francisco the daily story of some sensation which interests the people is distorted, every fact opposed to the conclusion the news-senders wish to attain being suppressed or perverted. To

any one with a particle of manliness, or a sense of fair play nothing can be more offensive than such misrepresentation of proceedings which he has, perhaps, himself witnessed.

The least of these frauds are gratuitous additions and comments such as "stammered the witness reddening to the ears;" or "the witness answered with some confusion;" or "with a guilty look of embarrassment."

Such phrases are introduced simply to prejudice the witness's standing before the reading public, and are generally wholly false.

The attempt has been sometimes made to raise the standard of an occupation degraded by abuses by applying to it scientific methods, and investing it with the character of a legitimate art such as the practice of medicine, or navigation. But the enthusiastic people who have tried such experiments have usually been rewarded as are the girls who marry drunkards to reform them.

M. L. Vallain, sworn-writer and expert in France, exclaimed "the verification of handwriting is within the province of the profession I have adopted, and I do not think it proper to refuse my aid to this kind of investigation, but I must add that I am far from seeking this kind of work."

And no wonder when so experienced and able a savant as M. Bertillon expended all his ingenuity and power in supporting the accusation of Dreyfus at the order of a then all-powerful faction in France. And not content with merely averring what his supporters wanted proven, he launched into the most extraordinary and imaginative hypothesis of a key word "*interet*" which he found pressed on a piece of blotting paper; and tried to prove by the calculation of probabilities that Dreyfus had forged (?) the bordereau, by means of a "gabarit" or key plan laid under the paper.

The Court of Cassation submitted this scheme to Darboux, permanent Secretary of the Academy of Sciences, Paris; Appell, Dean of the Faculty of Science, of Paris; and Poincaré, Professor of Mathematics of the same Faculty, who reported:

"That the system was without scientific value (1) because the calculus did not apply to the subject; (2) because the reconstitution of the bordereau was false; (3) because the rules of the

calculus of probabilities were not correctly followed. In a word the authors have reasoned badly on false documents."

If so scathing a report of the work done by the distinguished Bertillon can be made by men of the class of the signers of the report there is little hope of raising the tone of this study through the labors of those who exploit it merely for gain.

Yet when its province is recognized as within that of experimental psychology, entirely capable of being conducted like other investigations of the faculties of man, by exact measurement and numerical statement the shallow pretenders who have from time immemorial infested it will disappear.

PERSIFOR FRAZER.

Popular Science Lecture Series, Winter Course.

Delivered in Association Hall Y. M. C. A., Philadelphia, January 14, 1907.

GOLD AND SILVER PRODUCTION IN 1905.

Owing to the interruption of all normal business in the various parts of California, and particularly in San Francisco, caused by the earthquake that devastated that city last spring, the report of the United States Geological Survey on the production of gold and silver during 1905, has been unavoidably delayed. It is now, however, available and will be of interest to the whole mining world, as it contains not merely the statistics of production but minute and interesting data concerning the derivation of the gold and silver product from placers, from dry or silicious ores, copper ores, lead ores, zinc ores, copper-lead or copper-lead-zinc ores, and lead-zinc ores.

The author of the report is Mr. Arthur Lindgren. The figures showing the production of gold and silver, in approximate distribution by States and Territories, are the result of conference and adjustment between the Geological Survey and the Bureau of the Mint, and are accepted as final by two bureaus. The total production of gold was 4,265,742 fine ounces valued at $88,180,700; the total production of silver was 56,101,600 fine ounces valued at $34,221,976, making an entire total value of $122,402,676.

The production of gold in the United States for 1905 represented an increase of $7,716,000 in value over the production of 1904. The rapid advance in gold production which began in 1902, but temporarily halted from 1901 to 1903, was resumed in 1904. This increase in 1904 over the output of 1903 was approximately $7,000,000, and in all probability the increase in 1906 over 1905 will be at least the same amount. The chief sources of the great increase are as follows: Alaska added about $6,000,000 to its output of $9,160,458 in 1904, and Colorado, Nevada and Utah added about $1,000,000 each to their product of the previous year. On the other hand, decreases

are noted in Arizona, Idaho and other States. The States producing over $1,000,000 in gold rank at present in the following order: Colorado, California, Alaska, South Dakota, Nevada, Utah, Montana, Arizona, Oregon and Utah.

The production of silver in 1905 represented a decrease of 1,581,200 ounces in actual output, but in spite of this the increase in the average price 4 cents an ounce (from 57 cents in 1904 to 61 cents in 1905) effected an addition to the value in 1904 of $765,952. Two years of better prices for silver have thus far failed to stimulate the production. The record figures were attained in 1892, when the output was 63,500,000 fine ounces, valued at $55,-662,500. A still further advance to the maximum of somewhat over 70 cents has taken place in 1906, but it is not likely that the year will show startling additions to the output for 1905. The increase should be more marked in 1907, and will probably be rather derived from copper ores and dry silver ores than from lead ores.

The decrease in the quantity of silver is specially noticeable in Colorado and Utah; to a slight degree also in Montana. On the other hand, Nevada and Idaho materially increased their output. The States producing over 1,000,000 ounces rank at present as follows: Montana, Colorado, Utah, Idaho, Nevada, Arizona and California.

The output of gold and silver in the United States is ascertained by the Geological Survey by the method of "Mines reports," that is, by direct inquiry from the producing mines. On the other hand, the Bureau of the Mint collects its data concerning the two metals by recording the quantities and sources of bullion deposits of the United States mint and assay offices, and by statements from the smelting and refining establishments detailing the quantities and sources of the metals produced. Statistics obtained by these different methods agree strikingly in the totals for the United States, but differ more or less in detail. Reasons for this are set forth in the report

The Government Irrigation Project at Roosevelt Dam, Salt River, Arizona.

By Prof. Oscar C. S. Carter.

Arizona has two well marked physiographic divisions; there is a high plateau comprising the northern half of the State which is from 4000 to 8000 feet above tide. The southern half of the State is a low desert area which, however, is mountainous in the eastern part. An escarpment or wall separates these two parts of the State. This escarpment enters from Utah on the north and trends from the northwest to the southeast; it is the southern border or edge of the Colorado Plateau, which is named after the Colorado River, which has cut a gorge for 200 miles through this plateau, which is from 4000 to 6500 feet in depth. This is known as the greatest scenic wonder in the world—the Grand Cañon of the Colorado River.

The high parts of this plateau in the north are more than a mile higher than the low desert in the south. It is this low country that is to be irrigated. It is out of the question to irrigate the high plateau country, because the Colorado flows through the Grand Cañon, which is so deep that the water could not be pumped from it and the prospects for artesian water on this high plateau are not encouraging.

The student of a quarter of a century or more ago had a very vague and erroneous idea of a desert, and if we examine the text-books of that time we will not wonder much at these strange conceptions of our childhood. A low and level expanse of sand, whirling in columns and drifting in heaps might describe limited areas of the African deserts but could have no reference to the deserts along the Mexican boundary line, the Yuma Desert, the Colorado Desert, Death Valley Desert, or the deserts of Nevada. Great mountain ranges with serrated crests gaunt and forbidding, enormous lava flows with rough and jagged surfaces. The great

variety of cacti with their beautiful but scentless flowers. Cacti which vary in height from the low egg-shaped forms but a couple of inches in height, capped with a yellow flower, which one sees on the Colorado Plateau, to the enormous cereus giganteus or suguarro of the Mexicans which rears its candelabra-like arms thirty and forty feet above the desert floor, reminding one of the flora of a past Geological Age. The sage, the Mexican greasewood, the mesquite, the occasional dense growth of chapparal took no part in the description of a desert in our childhood days.' In an article on Death Valley by the author (see JOURNAL OF FRANKLIN INSTITUTE, Sept., 1902,) the reference is made to several interesting and valuable articles on the deserts of the United States. Notably, one by Captain Gaillard, of the Mexican Boundary Commission, on "The Perils and Wonders of a True Desert.' Another valuable and more recent article on the "American Desert," by Robert T. Hill, formerly Geologist of Texas. These articles give one a clear conception of our deserts as they are. Let one read the Report of the Mexican Boundary Commission, which is handsomely illustrated and is a valuable document especially from a geographic standpoint. It treats of a region most of which was practically unknown and new country before traversed by the engineers of the commission and which does not contain as many inhabitants as some of our rural towns. Some of the deserts along this boundary, like the Yuma and Colorado Deserts, are veritable Saharas and are even hotter and more arid. The Colorado Desert is named from the River of that name which flows through it and empties into the Gulf of California. This river could not exist in this region were it not fed by the snows and lakes of the Rockies, and yet these deserts bloom like a garden when irrigated; the soil is fertile, no plant growth has ever exhausted it; the only thing wanted is water, when it will produce five crops of alfalfa grass in a year. When the Government irrigation projects are finished the United States will take the lead as the foremost country in the world where irrigation is practiced on a gigantic scale. It must not be thought for one instant, however, that irrigation was not practiced extensively here before the Government Reclamation Service was esablished. Major J. W. Powell, formerly Director of the U. S. Geological Survey, in his statement before the Committee of Irrigation of the House of Representatives in 1890, stated: Mr.

Chairman, I have prepared a table by States and Territories of the land irrigated.

IRRIGATED AREAS TOTALS.

States.	Under ditches constructed or projected. Acres.	Irrigated and under ditch. Acres.
Arizona	455,600	175,000
California	6,000,000	3,000,000
Colorado		2,000.000
Idaho	740,000	400,000
Montana		348,000
Nevada		75,000
New Mexico	1.360,000	638,000
Oregon	191,000	119,000
Utah		802,000
Wyoming	1,227,819	500,000
Total		8,057,000

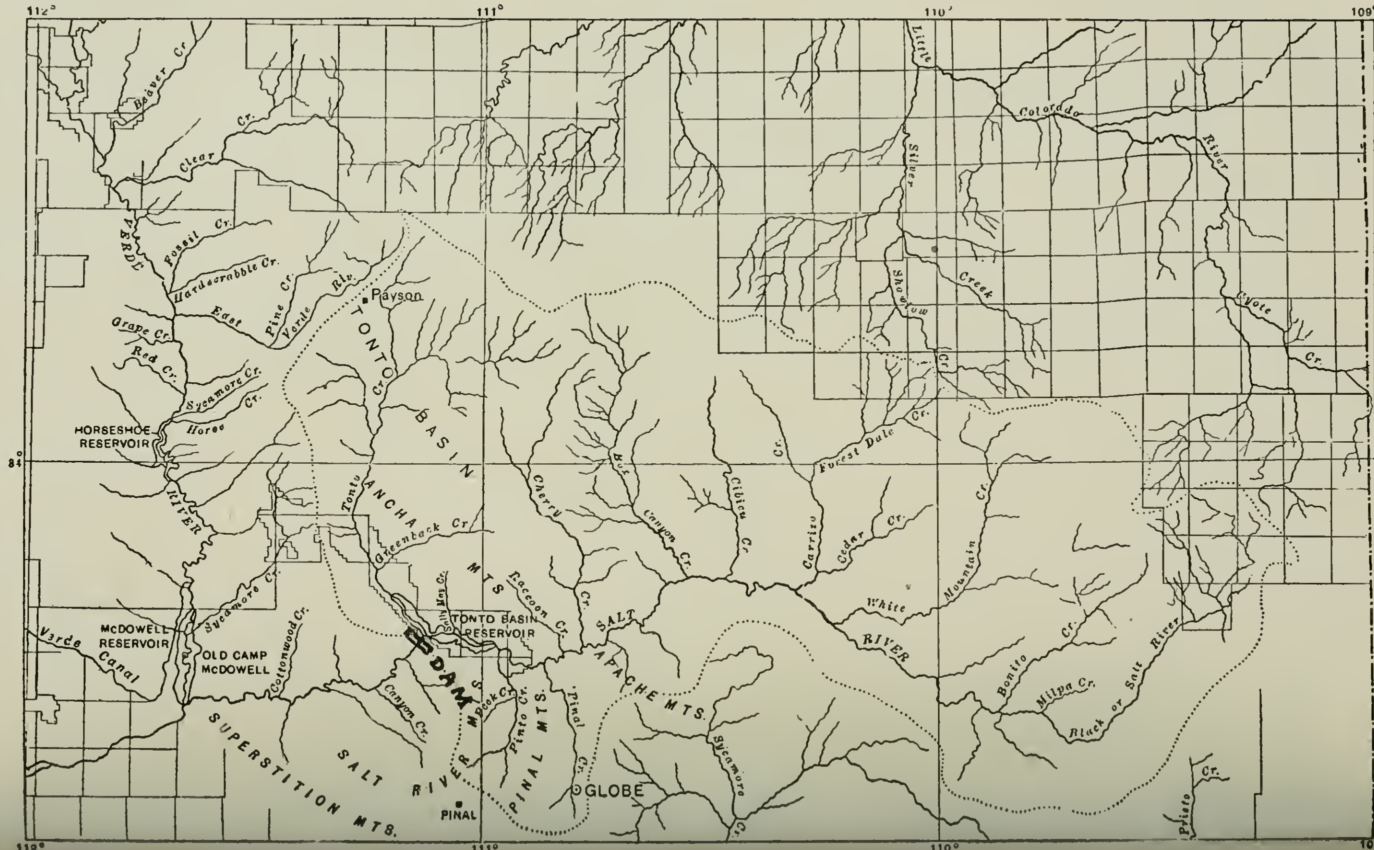
He states in a foot note, however, that the figures are not comparable among themselves as they are derived from many sources and by various persons, each having different purposes and ideas as to what constitutes irrigation. Mr. F. H. Newell, Chief of the Reclamation Surface States, in an article on the Hydrography of the Arid Regions (12th Annual Report U. S. Geological Survey, Part II, page 312,) that as far back as 1889 the following canals were reported in the Salt River Valley in Arizona, the water being taken from the Salt River:

Canals.	Length. Miles.	Canals.	Length. Miles.
Arizona	40	Utah	6
Grand	22	Farmers	5
Maricopa	14	Highland	22
Salt River Valley	18	Dutch Ditch	4
San Francisco	9	Monterey	4
Tempe	19	Griffin	3
Mesa	9		

It must be borne in mind that these 175 miles of canals are in Maricopa county alone and the water is drawn from the Salt River, which is to supply the water for the enormous Roosevelt dam, 285 feet high. The Gila River in Yuma county, into which the Salt River empties, furnished water in 1889 for more than 118 miles of irrigating canals.

U. S. GEOLOGICAL SURVEY

WATER-SUPPLY PAPER NO. 73 PL. I



DRAINAGE LINES OF SALT RIVER BASIN

These figures show that irrigation was carried on extensively if not always scientifically before the Government took the matter in charge. The birth of the Government Reclamation Service marks a new dawn in the era of irrigation, because the highest engineering and scientific skill will be brought to bear upon these most stupendous projects which dwarf into insignificance by their immensity, former irrigation projects.

Major J. Wesley Powell was a remarkably well-informed man. After serving as Director of the U. S. Geological Survey for a number of years he was appointed Chief of the Bureau of Ethnology. It is an interesting fact that a number of the leaders of the Bureau of Ethnology to-day were formerly members of the U. S. Geological Survey. The present Chief, Mr Holmes, Dr. Fewkes and Mr Magee are among the leaders who were formerly geologists. There is little doubt but what their attention was first drawn to ethnology by their investigations in the West and their contact with the various Indian tribes and their familiarity with the various ruins and cliff dwellings. Powell was what might be termed a broad gauge man, while he had the knowledge of the specialist in many cases; his learning was rather of that broad and general character which gives one the power to correlate, classify and utilize scientific knowledge of many subjects. When he was testifying before the Committee on Irrigation of the House of Representatives he made some exceedingly interesting and valuable statements about the destruction of timber in the arid region which are ecrtainly worth repeating. Timber is an exceedingly important, though scarce, production in the arid region and for the Roosevelt dam across the Salt River more than 3,000,000 board feet, 800,000 feet of lumber, and about 1,100 poles have been cut from the Government Reserves on the Sierra Ancha Mountains, where a saw mill was erected, notwithstanding this will be a dam of solid masonry. Powell was asked by the Chairman about the rainfall on the mountains and in the valleys of the arid region. Powell explained to the committee that the rainfall is very irregularly distributed in the arid region. It is concentrated on the mountains and very little falls on the great valleys and plains. It is through the use of these mountain streams that 100,000,000 acres of land can be irrigated and redeemed, while the rain that falls on the valleys and plains sinks through soil and

sand and a great deal is lost by evaporation. He then placed a colored map before the committee which showed the forest areas in the arid region. This map was made from surveys carried on and was fairly accurate. These are of two kinds, first, the forests on high mountains and plateaus, which are the forests of commercial value, the pine, fir, spruce and sequoia. The area covered by forests of this class is not one-tenth of the whole; it is about 125,000 square miles, but all are on high mountains and plateaus and are not dense and could stand on one-fourth the space. In addition to these there are forests of some value covering a large area; these are pinion or nut pine, cedars and dwarf oaks. They are available for fire wood, fences and minor purposes. The area covered by these forests is a little over 130,000 square miles, so that within the arid region the extent of forest is about one-fifth and is scattered.

What Powell wanted to point out was the relation of these forests to agriculture and other industries of the country. The lower limit of the commercial forests varies from 4500 feet above the level of the sea at the north to about 6000 or 7000 feet above tide at the south, and from this lower limit the timber rises 4000 feet into the region above. Where these great commercial forests are, great snow falls occur during the winter and in the summer frosts may be expected, so that by reason of the altitude and temperature the region covered by these commercial forests is not fit for agriculture. The forests are being rapidly destroyed and it is of their protection and relation to agriculture that Powell spoke. The forests are utilized by the people who are engaged in agriculture in the valleys from five to one hundred miles away. They are burned as fire wood and utilized for mining purposes.

Mr. Herbert—"And the railroad companies also use them largely for cross-ties."

Major Powell—"Yes, sir; but ordinarily that is not a very great use. The mining use is great, the domestic use is very great, and the use for railroad purposes is of little importance. A man who cultivates a farm in this region usually has no timber on his tract. The timber with which he builds his house and fences and uses for fire wood grows many miles away. Hence they build roads into the cañon and bring the timber down, and they construct tramways and slides down the mountain sides and flumes, taking it out on streams of water and floating it down. So

that the timber region is always in another region from the farming industry. But the timber is being rapidly destroyed by fire.

U. S. Reclamation Service.

View showing the rank growth of cultivated flowers when watered frequently. Illustrating how an ordinary cottage can be beautified in Salt River Valley, Ariz.

That which man uses is insignificant. Man himself, taking the grand aggregate, has made no impression on the forests of that country. They grow faster than man has heretofore cut them

down, and if they could be protected from devastation by fire the use made by man would never injure the forests—not until a vastly denser population is gathered. These forests are composed of coniferous trees that are rich in inflammable resinous substances; the bark of trees is exceedingly inflammable and the pine needles that fall upon the ground are inflammable and all give rise to great fires and vast areas of forest have thus been destroyed. A little more than ten years ago I mapped the Territory of Utah and in making that map I delineated not only the existing forests, but the burned forests and found that at that time one-half of the forests of the Territory had been burned. I have seen one fire in Colorado destroy more timber than has been used by man from the migration to Pike's Peak up to the present time; and I have seen several such fires in Colorado. This past season, as an attaché to the Senatorial Committee investigating the question relating to the arid lands, I passed through South Dakota, North Dakota, Montana, Washington, Oregon and Idaho by train. Among the valleys, with mountains on every side, during all that trip a mountain was never seen. This was because the fires in the mountains created such a smoke that the whole country was enveloped by it and hidden from view. That has been the experience for twenty odd years, year by year, in this region. The geographical work of our Survey is cut off during the very dry months by the smoke; the men can not get lines of sight from height to height through that country because of the fires produced in the mountains and the smoke settling down over the land. In the last twenty years one-half of the timber has been burned. Where timber burns in this manner it springs up again; the lands as forest lands are not destroyed by these fires, but the timber itself is destroyed, and it is of slow growth."

Powell testified in 1890 and of course conditions are not now quite the same and the more recent careful surveys might change these estimates somewhat, but as late as the summer of 1905 while stageing a hundred miles through the heart of the Sierras the author saw forest fires that were doing great damage and even impeding travel.

Fifteen years ago there were very few irrigation engineers in this country. Irrigation engineering was just being recognized as a distinct branch and was engaging the attention of some of

the prominent engineers in the United States. The early stages in the development of irrigation had about passed and irrigation projects on a large scale were being considered and the construction of permanent and substantial works required a special personal knowledge which could best be gained by visiting a country where irrigation was conducted on a grand scale and where great engineering works of permanent value were constructed. Accordingly Mr. Herbert M. Wilson, C.E., was commissioned to visit British India and confine his observations to those features especially, which will be of greatest importance and benefit to

U. S. Reclamation Service.

View showing the different varieties of Cactus growth under cultivation at Insane Asylum near Phoenix, Arizona.

those who conduct irrigation on a large scale in the arid and semi-arid regions of the United States rather than to describe works of a novel and astonishing character. There is one rather curious and interesting statement made in the abstract of the Third Annual Report of U. S. Irrigation Survey, 1890-1891. Speaking of Mr. Wilson—"He shows the great benefits financially derived from the canals of India, and points out how in many localities the topography, climate and water supply re-

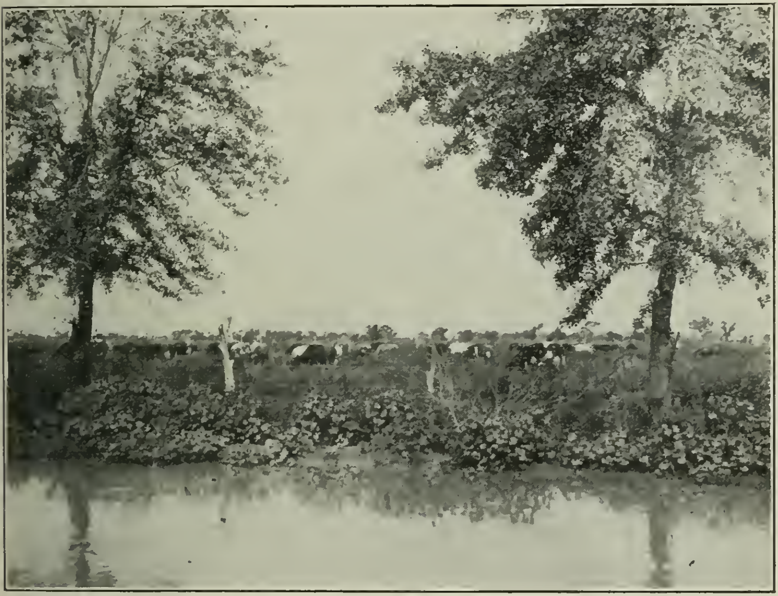
semble those of our arid West. Of course with our lower mountain ranges and smaller rivers, Americans cannot construct such great canals, nor are we called upon to build such gigantic structures for the control of water supply, but, on the other hand, the smaller irrigation systems of India serve as a means of comparison and enable us to draw conclusions as to the excellencies or defects of our own methods."

The above statement shows that fifteen years ago such irrigation projects as the Government engineers are working out and finishing to-day were never conceived or even dreamed of as being possible. Mr. Wilson said before his departure he was busily engaged in reading all the books and reports on Indian irrigation procurable, in order to plan the trip so as to see the most in the least space of time. Through the co-operation of the Director of the United States Geological Survey he left Washington in 1889 with a grip full of letters of introduction to various secretaries of public works, departments in India and to consular officers abroad and to prominent English engineers. He made a successful observation journey and examined only the principal canals navigable and non-navigable and neglected the deltaic and inundation canals, as he said there was little or no probability that such works will ever be constructed in the United States. He said: "India stands pre-eminent for her gigantic engineering undertakings. No other country has so vast and so fertile an expanse of territory, with such convenient slopes for the construction of canals, and at the same time such an abundant water supply. In general there is great similarity between the climate and topography of the great northern plains of India and portions of our arid West, especially the eastern slope of the Rocky Mountains and the Great California Valley. Central India and the Deccan have many features in common with the central arid Territories, particularly portions of Northern Arizona and Southern Utah. The climate is as similar to that of our central Territories as is the topography. The average annual precipitation rarely exceeds thirty inches, while the precipitation during the autumn crop varies between two and six inches. The topography of the upper Mutha Valley seemed very familiar. Had I been suddenly transported in my sleep to Northeastern Arizona the similarity of the topography of the two regions could not have more strikingly impressed me. At Lake Fife the Mutha

River makes its exit through a narrow cañon similar to those of the mesa country in Northern New Mexico and Arizona and the cliffs are similar in their abruptness and sharpness of outline to the mesa cliffs of our Southwest. Wherever the soil is uncultivated it is covered with a low scrubby grass dried and parched by the sun. At the canal edge the barren slopes are suddenly merged into endless green and well cultivated fields. The slopes of the hills are rocky and barren, covered with a growth of low trees among which babul or mesquite is the most prominent."

One recognizes in the above description a kind of topography

U. S. Reclamation Service.



Excellent pasture in Salt River Valley. The Result of Irrigation.

which is common in the arid Southwest, although the rainfall is much less with us. The Gila River is the principal stream in Southern Arizona. It empties into the Colorado River near the town of Yuma. Its principal tributary is the Salt River, which lies south of the center. The Upper Salt drains that portion of the territory east of the center. The largest tributary of the Salt River is the Verde which drains the central part of Arizona. The Salt River brings more water to the main trunk of the Gila

than the Gila carries before they join. This is due to the fact that the Salt River rises in the mountains, and the peaks from 10,000 to 11,000 feet are high enough to get a generous rainfall. The Salt River drains a mountainous country east of where the Verde joins it. There is another tributary east of this called the Tonto Creek. A half a mile below this stream the river enters a great cañon with precipitous walls and a narrow bottom. In this cañon is located the great Roosevelt dam of the Salt River.

Mr. A. P. Davis in Irrigation Paper 73 advances another reason why there is more rainfall southwest of the Colorado Plateau in Arizona than there is on the plateau—"Another partial explanation is found in the meteorological condition. The moisture of this region is brought from the Pacific Ocean and the Gulf of California by the prevailing southwest wind. As this wind ascends the elevations toward the Colorado Plateau its temperature is lowered which reduces its capacity for holding moisture and increases its relative humidity. When this quantity reaches 100 per cent. in any part, precipitation occurs. This influence continues until the wind passes the summit where the process is reversed. Therefore, the hydrographic resources of the country immediately southwest of the Colorado Plateau is disproportionately great when compared with those to the northward. For instance, the precipitation at Fort Apache, as shown by a mean of twenty years observations, is $19\frac{3}{4}$ inches, the elevation being 5,050 feet, while the precipitation at Holbrook, at an elevation of 5,047 feet, on the northern slope, is 8.47 inches, as indicated by a mean of ten years observations. This is an important fact especially when taken in connection with the fact that the great areas of valley land with a semi-tropic climate lie in the southwestern portion of the Territory, and are easily covered by the streams which are formed by the conditions above described, and which constitute the main features of the great Gila River system."

The following extracts, quotations and general information pertaining to the Roosevelt dam and its construction are taken from Irrigation Paper No. 73 by A. P. Davis: In the deep cañon where the dam is being built a great deal of silt had accumulated and borings to bed rock were made at thirty-one points in the cañon. In the upper end they found from 44 to 64 feet of river silt. The dam of course must be built on solid rock,

so more than a quarter of a mile farther down the cañon they found by boring a favorable site where the river silt was less than half the above amount. He says: "The gorge on Salt River is an especially favorable site for a masonry dam, and the most permanent, conservative and secure form of high dam that is known to engineering science can be constructed. The formation is sedimentary, with the strata inclined at an angle of about 30° to the horizon dipping toward the reservoir, a most favorable

Water Supply Paper 73.

Salt River Dam Site Looking Downstream.

condition for retaining stored waters and for the stability of the dam. The foundation and abutment of hard, tough, fine grained sandstone are all that could be desired. Building stone of the same material is at hand above the site. Good Portland cement can be made in the vicinity. Sand for mortar can be obtained from the river bed, but will have to be washed and screened, and it is thought that the best plan will be to manufacture sand by crushing quartzite, which occurs in abundance near the site. This will provide an ideal sand, and as power is abundant its cost will

not be great. The dam must be so designed and constructed as to be safe from destruction by any or all of the forces acting upon it. It is possible for a masonry dam to fail in any one of three ways: 1. By overturning; 2, by sliding on the base, or on any horizontal joint; 3, by crushing its foundation or masonry near the base. A factor of safety of at least two is secured against overturning by so designing the dam that under all conditions the resultant of all the forces acting will fall within the middle third of any horizontal joint. This also eliminates the possibility of any tensile strains in the masonry, a very desirable result. The same condition also secures safety against sliding, which is insured in a still greater degree by constructing the masonry of random rubble, and by the use of hydraulic mortar, bonding it together and to its base, so that it becomes a true monolith—a part of the solid rock to which it is firmly joined. Under these conditions a large margin of safety is provided, as the structure cannot slide without shearing the masonry. In addition to these precautions the dam planned is to be built in the form of a circular arch, greatly increasing its safety against both sliding and overturning. In fact neither can occur without overcoming the gravity and cohesion of the masonry, and also crushing the masonry or abutments. The total factor of safety against failure by the first and second methods can not be exactly known, but it is unquestionably very great. The recorded failures of high masonry dams are as follows: At the Habra dam in Algiers poor hydraulic lime was used, and a red earth with a large percentage of clay was used in the mortar instead of sand. This combination made a poor mortar, and the rock was also poor, being a porous calcareous grit. It is supposed that the failure occurred by the crushing of the foundation under a computed stress of 13.3 tons per square foot. At the Bouzy dam in France the foundation was fissured and permeable and not on solid rock, allowing an immense upward hydrostatic pressure; the section was so light as to permit great tension in the masonry in the back. It was straight in plan, and when the reservoir was nearly filled the central portion of the wall was shoved forward about a foot, causing ruptures and leakage. This was afterwards repaired and the foundation reinforced. Six years later when the reservoir was full the dam suddenly overturned at a plane about 33 feet below the top. The above recited defects were the un-

doubted cause. At the Puentes dam in Spain the central portion of the dam was founded upon piles driven in earth. When the rising water applied a heavy hydrostatic pressure, this portion of the foundation suddenly gave way and left the top and ends of the dam standing in the form of an arched bridge.

"The dam at Austin, Texas, was an overflow dam built of limestone rubble, the stone being very soft and of poor quality. The foundation was on a geological fault and was of soft lime-

Water Supply Paper 73

Salt River Reservoir Site Looking Upstream.

stone, in thin horizontal layers, which had little adhesion and probably very little friction upon one another, and the failure, which was by sliding, is supposed to be due to this fact.

"In all four of the above cases the foundation was defective. In three the stone was poor and in two the mortar was poor. All were straight in plan except the Puentes, which was polygonal in plan and arched up stream. This dam seems to have been very well planned and constructed except for one fatal defect of being founded on piles instead of solid rock.. All of the defects in

these failures can easily be avoided in the proposed dam by a reasonable application of care and skill. The proposed dam is designed to be 217 feet above low water in the river at the dam site and to store water at a maximum depth of 190 feet. The total height of the dam above lowest foundation will be about 247 feet."

Since Mr. Davis' report was written the dimensions of the Roosevelt dam have been increased (see 4th Annual Report Reclamation Service.)

Length of dam at datum	210 feet
Height of spillway above mean low water	220 feet
Height of roadway above mean low water	240 feet
Total height of dam from foundation to parapet	285 feet

This dam will back the water up Salt River about 16 miles and up the Tonto Creek nearly as far. It will produce a lake over 25 miles long and from one to two miles wide The reservoir will have a capacity greater than that of any other artificial reservoir in the world.

Spillways 20 feet deep will be excavated in the solid rock sides of the cañon and the rock used in the construction of the dam.

The location lends itself admirably to a curved form of dam, this form containing but little more material than a straight one of the same section. The proposed structure is to be built on a circular curve, convex up stream, the back having a radius of 400 feet and the face a shorter radius from the same center The dam is to be of uncoursed rubble masonry and to have a section on modern conservative ideas as a simple gravity structure, and the added stability due to its curved form will greatly increase its factor of safety. The rock of which the dam will be constructed will be excavated from the spillways and is a tough, close-grained sandstone. Two cubes with edges of two inches were cut from samples of the rock to be used in Salt River dam and crushed in the testing machine at the United States Navy Yard at Washington. Sample No 1 crushed at 59,650 pounds, being 14,912 pounds per square inch or 1,074 tons per square foot. Sample No. 2 crushed at 100,000 pounds, this being 1,800 tons per square foot. These results are so high that the strength of the rock is entirely eliminated from the discussion. The rock is to be used in as large pieces as practicable, in order to make the number of

joints as few and the quantity of mortar as small as may be. It is estimated that rock will occupy 70 per cent. of the structure. Fifteen per cent. will consist of cement mortar in which the stones are bedded and fifteen per cent. will consist of cement concrete rammed into vertical joints. Taking the weight of the mortar as 115 pounds per cubic foot and that of the concrete as 130 pounds, the masonry will weigh as nearly as can be estimated 146

Water Supply Paper 73

Drilling party on Salt River. Line A of Borings.

pounds per cubic foot. On this estimate the strains have been computed and the section of the dam designed. As the dam is to serve as a highway, a top width of sixteen feet has been adopted with parapets along the sides. The pressure on the top when the reservoir is full will be 15.9 tons per square foot, computed on the assumption that the dam is a rigid-monolith and non-elastic.

Specifications in Brief for the Construction of the Dam.

Diversion of the River.—The diversion of the river will be accomplished by means of sheet piling driven as deeply as practicable directly across the cañon, beginning at south side and reaching as nearly as practicable to bed rock, the piling to be re-enforced at and above the surface by a heavy wall of sand and gravel excavated from the site of the dam, the water to be diverted through the outlet tunnel which will be constructed in advance.

Foundation.—All earth, sand, gravel and boulders, disintegrated loose and seamed rock will be excavated and removed from the entire area of the base of the dam in order to secure a firm foundation on solid rock. Explosives shall not be used in excavating the rock unless absolutely necessary, and then only in small quantities in shallow holes to avoid fracture of the rock forming the foundation of the dam.

Masonry.—The main body of the dam shall be constructed of broken range cyclopean rubble. The stone shall be quarried from the walls on each side of the cañon. If sufficient quantity of hard fine grained stone cannot be obtained in these spillways it shall be quarried elsewhere. All stone shall be washed and laid in Portland cement mortar. No mortar joint in the face shall exceed one inch in thickness. The body of the dam shall be composed of as large stone as practicable, well shaped and laid so as to break joints and bond in all directions. Vertical joints between the stones must be nowhere less than four inches and must be filled and rammed with Portland cement concrete. The aim shall be to use the largest proportion of stone and the smallest proportion of mortar and concrete. Facilities shall be provided for handling stones weighing twelve tons, and large stones shall be used as far as practicable.

Mortar and Concrete.—All mortar used in the lower thirty feet of the dam shall consist of 1 part of Portland cement, 2 parts of good sharp sand; and all concrete used in this portion of the dam shall consist of 1 part cement, 2 parts sand and 3 parts of broken stone as will pass through a screen with meshes 2 inches square. The mortar and concrete used in the upstream face of the dam for a thickness of 20 feet shall be of the quality above specified. In all parts of the dam which are more than 20 feet from the up-

stream face and 30 feet from the base the mortar shall be 1 part Portland cement, 3 parts sand, and the concrete one part Portland cement, 3 parts sand and 4 parts broken stone of a size to pass through a screen with meshes 2 inches square. All mortar and concrete shall be thoroughly mixed and used so promptly that there will be no danger whatever of incipient setting of the cement previous to the completion of the masonry in which it is placed. No cement shall be used until at least sixty days after its manufacture and not until it shall show satisfactory tests according to chemical and physical requirements adopted by the Ameri-

U. S. Reclamation Service.

Government Road Salt River Project Ariz. just over Roosevelt Dam site.

can Society of Civil Engineers. The reason for using a larger percentage of cement in the base of the dam is that here will be the greatest pressure, and the higher percentage of cement will give a greater power of resistance to crushing. The higher percentage of cement is maintained on the water face of the dam all the way to the top in order to render it as nearly impervious as possible. It may be confidently predicted that a masonry dam at the proposed site, constructed on the above plans and specifica-

tions, would be absolutely permanent, safe, solid, and secure for all ages to come, as truly as the everlasting hills, of which it will become an integral part."

SEDIMENT.

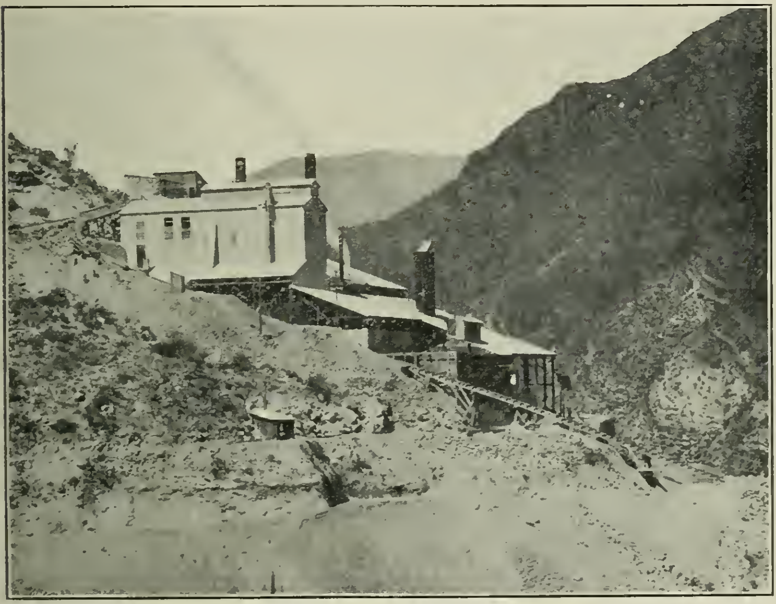
Mr. Davis also states that "most of the streams of the Southwest carry considerable solid matter which causes annoyance in canals and has a tendency to fill any reservoir constructed on the stream. This is true of the Rio Grande, Colorado, Pecos, and Gila Rivers. There is silt also in the waters of the Salt River as shown by its occurrence in the canals, but it is not nearly as abundant as in the streams above mentioned. The basin tributary to the Salt River reservoir lies in large part in high timbered country and includes the Apache Indian Reservation. The reservation is almost entirely covered with forest and grass. The Tonto Creek and a few other tributaries deliver some silt during floods. From observations of the amount of sediment carried he found the amount so small as to be almost negligible, but the discharge during the year was far below the normal. It would probably be 100 years before the loss of storage capacity would be seriously felt and it would be necessary to resort to methods of clearing it out. The greatest amount of sediment will usually be found in the lower layers of water and it will therefore contribute to the maintenance of the storage capacity to drain all the waters from the lowest possible point at all times. Two outlets are provided in the form of tunnels 10 by 13 feet, one around each end of the dam. Whenever water begins to run over the spillway the gates must be opened to full capacity not only to draw off the maximum quantity of sediment but to reinforce the spillway. The plan adopted then to facilitate the discharge of sediment and reinforce the spillways is to draw all water from the reservoir through large openings directly on the bottom. The two tunnels will be dug through the solid rock, one on each side of the cañon."

POWER PLANT.

He further says: "In the construction of a great dam one of the most important elements is that of power. This is necessary on a large scale for drilling purposes, for handling rock, for mixing and handling mortar and for crushing rock to be used in concrete. In the present case it has been found possible and very de-

sirable to manufacture on the ground the large quantity of cement required in the dam. This would require about 300 horse-power day and night for grinding rock and clinker and for handling materials and running machinery. It is usual to provide such power by means of steam engines, but in the present case this is rendered very expensive by the scarcity of fuel. Coal in quantities, now costs $10 per ton in Globe, and the wagon haul to the dam site would nearly double this. A limited amount of

U. S. Reclamation Service.



Detailed view of the Cement Works. Roosevelt Dam.

wood is available, but to secure the large quantity which would be required if it were the sole dependence for power would involve a long haul. The best means for providing the necessary power is by the development of water power on the river. This will involve the construction of a diversion dam and canal, which can afterwards be utilized if required for sluicing accumulated silt out of the reservoir. The power developed can be used in the neighboring mines or in the valley below for pumping purposes. The proposed canal would head some distance above the reser-

voir, follow above its water line, and finally discharge just below the dam, with an available head of about 180 feet. It is designed to deliver 100 cubic feet per second, and to develop a net energy of about 1200 horse-power after deducting seepage, friction, and the losses in water wheels, electric plant, etc. It is designed to use 900 horse-power at the dam and 300 horse-power at the cement mill. The power plant will consist of three units of 300 kilowatts each."

Since Mr. Davis' report changes were necessarily made in the canal and power plant (see 4th Annual Report Reclamation Service.) The canal will be 19 miles long and have a capacity of 200 second feet. The water will be carried above the reservoir to a point below the dam and there discharged through turbine wheels under a head of 220 feet, developing 4400 horse-power, to be used in constructing the dam and pumping water for irrigation in Salt River Valley. The water wheels and dynamos were increased.

CEMENT MANUFACTURE.

The problem of furnishing cement at a reasonable expense was an extremely serious one. It is an isolated locality and there is a wagon haul of 40 miles over exceedingly rough and mountainous country to the nearest railroad, which is a branch road with light traffic and high rates. It was estimated that cement would cost at the dam about $9 per barrel, and as later calculations showed that at least 220,000 barrels of cement would be required in the construction, the total cost was prohibitive. It was finally decided to make a careful search in the vicinity for the rocks out of which cement is made, namely—limestone, clay or shale, and if found in abundance and right composition for the manufacture of cement then a cement plant could be erected and the problem solved. With this end in view search was made in the Tonto basin for limestone, clay and shale. Eight samples in all were sent in for analysis to the superintendent of the cement works at Colton, California. Samples 1 and 7 seemed to be the most satisfactory. No. 1 was a limestone near the dam site, very abundant and convenient. The analysis showed:

Alumina and ferric oxide	0.20
Magnesia	.60

Calcium carbonate	95.80
Insoluble residue	3.30
	99.90

No. 7 was a clay from the hills 3 miles north of the dam site, very abundant. The analysis of the clay showed:

Moisture	13.40
Silica	51.90
Alumina and ferric oxide	23.70
Magnesia	.97
Calcium carbonate	10.90
	100.87

The shales that they found were expensive to quarry and grind, so they were discarded as they would only have been used if no suitable clays were found. All shales were once mud or clay laid down in ancient seas or lakes, and when the water disappeared pressure consolidated the mud or clay into shale. Samples of the limestone and clay were sent to Mr. E. A. Duryee, superintendent of the cement works, for an experimental burn. He reported as follows: "The clay and limestone were ground separately and then mixed in the proportions of 6.18 pounds of limestone and 2.25 pounds of clay, making a raw mixture that tested 43 per cent. lime. As the limestone was very hard and therefore more difficult to make into cement than a softer material, fluor spar to the amount of $1\frac{1}{2}$ ounces or 1 per cent. was added. The materials were also ground quite fine, but no finer than is the practice in some cement works. The raw mixture was made into briquets and these after being dried were burned in a gasoline furnace. They burned to a good hard clinker of a good color.

ANALYSIS OF CEMENT.

Lime	63.56
Alumina and ferric oxide	10.40
Silica	22.85
Magnesia	.71
Alkalies not determined.	

TENSILE STRENGTH OF NEAT CEMENT BRIQUETS.

	lbs. per sq. inch
7 days (1 day in air, 6 in water)	410
14 days (1 day in air, then in water until broken)	690
28 days (1 day in air, then in water until broken)	775

These results proved that an excellent quality of cement could be made on the ground. Mr. A. P. Davis states: "The greatest difficulty is the scarcity of fuel. There is considerable wood in the reservoir site, mainly cottonwood and mesquite, which it will be desirable to clear out of the reservoir in any event. Wood is not suitable for burning cement clinker by modern methods, but if made into charcoal and then ground to powder would answer, or oil may be imported for the purpose from California. A large amount of power is required for grinding the rock and the clinker and a still larger amount will be necessary in the construction of the dam, for excavating to foundation, quarrying and handling the rock, mixing and handling the mortar, etc. If steam power were used for all these purposes the small amount of wood at hand would soon be exhausted and it would be necessary to haul wood a long distance or to import coal, either of which would be very expensive. Water power can be developed by diverting water from Salt River above the reservoir site, carrying it in a canal above the proposed lake and dropping it through a penstock just below the dam. By such means an ample supply of power can be obtained, available through the construction period and afterwards also if desired."

"The estimated cost of the cement plant, with modern machinery, capable of producing 300 barrels per day, as furnished by Mr. E. A. Duryee, is $91,000. With such a mill using charcoal for burning cement the cost of manufacture would be approximately $2 per barrel. It was finally determined to burn the cement with crude California petroleum. Eleven gallons are required to burn a barrel of cement. The contract price was $3.48 per barrel, delivered at the cement mill in quantities of 3000 barrels monthly. The oil is hauled by rail from California to Mesa, Arizona, thence by traction engine 24 miles and by mule teams 37 miles to Roosevelt. (See 4th Report Reclamation Service.) The road from Globe to Payson passes through the reservoir almost its entire length. In case of the construction of the dam this road would be submerged and it will be necessary to provide a new one around the reservoir. If it were deflected to the east it would be thrown into an exceedingly rough mountain country, where the construction would be very expensive and the road beset by heavy grades. By passing to the west of the reservoir it would be necessary to use the dam as a viaduct and to

build bridges across the spillways. There would not be a great amount of road constructed and this plan would be far cheaper and furnish a much better road than could be built east of the reservoir."

Twenty miles of road were afterward built to connect Globe with the dam site. Altogether it has been necessary to construct 110 miles of road, part of which replace roads that will be flooded by the reservoir.

In January, 1906, the Reclamation Service issued the following statement for the public:

ARIZONA: SALT RIVER PROJECT.

This project contemplates the construction of a large storage dam at Roosevelt, Ariz., 270 feet in height, which will regulate the supply of water from gravity systems for about 160,000 acres of land in the vicinity of Phœnix. When the dam is constructed there will be developed a large amount of power which will be utilized to increase the water supply in the Salt River Valley by means of pumping from underground sources. Early in 1904 contracts were awarded for the construction of considerable auxiliary work, power canals, sluicing tunnels, etc. A cement mill was erected by the Government and is now in operation, furnishing a first-class quality of cement to be used in the works. The construction of the dam will require 220,000 barrels of cement. The excavation for the power canals is completed, the lining of canals is nearly completed, and the work on the sluicing tunnel was finished Oct. 3rd, 1905. The contract for the construction of the large dam was awarded to J. M. O'Rourke & Co., of Galveston, Texas. It is understood that there are no public lands available under this project for homestead entry, the entire area having been filed upon by settlers, many of whom have gained title to the land. For information as to the possibility of acquiring lands by purchase from present owners, and other data of a local character concerning the soil and climate of the valley, apply to Mr. B. A. Fowler, President of the Salt River Valley Water Users' Association, Phœnix, Ariz. The irrigable lands under this project are tributary to branch lines of the Southern Pacific and Santa Fe Railroad systems.

ROCK ANALYSIS.

"The analyses of Silicate and Carbonate Rocks" is the title of a forthcoming bulletin (No 305) of the United States Geological Survey, which will be of interest to chemists and geologists. The author is Dr. W. F. Hillebrand, who collaborated in 1897 with Prof. F. W. Clarke in the preparation of a bulletin (No. 148) on the analyses of rocks, in which a chapter was devoted to a description of the analytical methods in use in the laboratory of the Survey. This bulletin was so favorably received by chemists that it was found advisable to republish in 1900 a portion of it in more extended form as Bulletin No 176. This was credited to Dr. Hillebrand and bore the title of "Some Principles and Methods of Rock Analysis." Since then two other treatises on rock analysis have appeared: "Manual of the Chemical Analysis of Rocks," by Dr. H. S. Washington (1904), and "Anleitung zur Gesteins-analyse, by Dr. Max Dittrich (1905). The former is based largely on Bulletin No. 176; the latter, while adopting some of the methods advocated in that bulletin, adheres more to methods which are in greater favor in Germany than in this country. They both differ from Bulletin No. 176 in devoting less space to a discussion of principles and to a determination of the less common constituents of rocks. They have not, therefore, rendered the Survey publication superfluous. On the contrary, since some methods have undergone improvement or been superseded by better ones, the time seems ripe for its republication in revised form.

The literature relating to analysis of silicates is extensive but scattered. Up to the time of the Survey's publication of Bulletin No. 148, no satisfactory exposition of the procedures to be followed or the precautions to be observed in analyzing silicates was in existence. The need of such guidance was especially felt in the search for some of the rarer constituents, or those which, without being rare, have been of late years recognized as occurring persistenly in small amounts. As the outlines of some methods and procedures set forth in those earlier bulletins seem to have been too meager for the use of students, many of them have received considerable elaboration in this last edition.

For the reason that the chief carbonate rocks form so important an element in the composition of the earth's crust, and the knowledge of their composition is of moment to the geologist as well as to the cement maker, who now makes enormous use of them, a special section devoted to their analysis has been added. The methods applied to their analysis differ in but unimportant respects from those used with the more siliceous rocks, since they are to a great extent themselves siliceous, contain essentially the same constituents, and therefore the same principles apply to both.

Special problems relating to the analysis of rocks of extra-terrestrial origin—the more or less strong meteorites—are not considered in this treatise.

Section of Physics and Chemistry.

Some Well Known Synthetic Chemicals and Their Relation to the Pure Food and Drug Act.

By Lyman F. Kebler.

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The word "synthetic" as used in the chemical world, means a combination of separate substances, elements, or radicals, which results in the formation of definite chemicals. The manufacture of acetanilide from benzol, or antipyrine from aniline afford good illustrations, inasmuch as in the manufacture of both several operations are necessary. The word "synthetic," however, has acquired an entirely different meaning which has been used to a considerable extent in the past, usually in an honorable manner, but often for the purpose of deceiving not only the public, but also the doctor as well. This feature has been claiming recognition in no unmistakable terms during the past few months. It is held by some that the mixing together of the various cinchona alkaloidal salts, in proportion as found by analysis of the cinchona barks, the same dissolved in simple elixir and colored with caramel, is a "synthetic elixir of cinchona bark." Other illustrations are the common headache mixtures which consisted in the past, and at present to a lesser extent, chiefly of acetanilide, sodium bicarbonate, or ammonium carbonate, and caffeine. These mixtures are at times so named as to lead to the belief that they are synthetic chemicals. In some cases a hypothetical chemical name, together with a structural formula, are attached to make the deception even more complete. Since the passage of the act, the acetanilide has been replaced in many instances by para acetphenetidin (commonly known as phenacetine) and antipyrine. This sub-

ject will be considered in a subsequent portion of this paper. It is also claimed that a so-called "raspberry extract" made up with various esters, dissolved in alcohol (grain or wood) colored with cudbear is a "synthetic raspberry extract." There are undoubtedly different views as to whether or not the latter claims are justifiable, but in the speaker's opinion, the first definition, or a similar one, is the only one that should receive any recognition in the chemical world. As a matter of fact, the latter is simply used to attract the attention of the public and has no basis for existence whatever.

The Pure Food and Drugs Act specifies that an article is misbranded if it fails to bear a statement on the label of the package "of the quantity or proportion of any alcohol, morphine, opium, cocaine, heroin, alpha or beta eucaine, chloroform, cannabis indica, chloral hydrate, or acetanilide, or any derivative or preparation of any such substances contained therein." The act also forbids the use of any poisons or deleterious ingredient in the manufacture of food products, or any agent which misleads or deceives in any particular. The two phases of the act just considered require, first, that the presence of certain habit forming drugs, shall be declared on the label, and second, no injurious agent, or agents, which deceive in any particular, shall be used in the manufacture of food products.

It can readily be seen by chemists familiar with the ingredients enumerated in the act that the phrase "derivative and preparation of same" is very comprehensive, which was undoubtedly the intention of Congress. This clause was undoubtedly introduced for the purpose of preventing or evading prosecutions under the law on pure technicalities. For example, it has been held by the defendant in a number of cases where a prosecution was brought, on the ground that a product contained the forbidden ingredient, morphine, that the ingredient present in the product under consideration, was not morphine, but morphine sulphate. The same position has been taken in other cases, for example, it is contended by some manufacturers that the introduction of cocaine through the medium of an extract of coca leaves, or by extracting coca leaves directly with the menstruum of the article, cannot be considered a cocaine preparation any more than could coffee be construed as a caffeine product. It is immaterial

how cocaine is introduced into a product; the fact of its presence renders such a product a cocaine preparation. Any other conclusion must be based on a technicality or is a mere quibble.

So far as the word "preparation" is concerned, as used in the act, there does not appear to be any question relative to its meaning, but this is not the case with the word "derivative." The term "derived from" as used in the tariff law of 1897, has not only been subject to decisions at the hands of the appraiser of the United States Customs Service, but has also been defined by the United States Federal Court (1899 Federal Reporter 719) and the United States Court of Appeals (102 Federal Reporter 603). The decisions arrived at are that the words "derive," "derivation," "derivative" must be interpreted as "made of," "prepared from," "produced from," "obtained from," and that the term "derived from" has its ordinary meaning of "produced from" and relates to the physical substance from which such product is obtained and *not to its chemical relationship.* In other words, if the manufacturer starts with alizarine and by partial replacement produces a dye, such dye is derived from alizarine, but not otherwise. The question under consideration in the above decisions was whether or not certain dyes were derived from alizarine. These precedents must undoubtedly be taken into consideration in connection with the recently enacted pure food and drug law, but the aims and objects of the latter are entirely different from those of the tariff law.

The meaning of the term "derivative," as used in the act, has been called into question because (para) acetphenetidin is classed as a derivative of acetanilide. There is no question but that (para) acetphenetidine is a derivative of acetanilide, both chemically and physiologically and resembles it in its tendency to habit formation, physiological action, and physical properties. Furthermore, Treasury dicision 13270 construes this chemical as an alcoholic medicinal preparation. The exact status of this product under the law therefore appears to be in a somewhat unsettled condition at present.

In this paper only a few of the synthetic chemicals that are affected by the Federal Law, will be considered. For the purpose of ready reference, it is deemed desirable to collect them into the following groups:

	Common names.	Synonyms and Chemical names.
1st. Alcohol Group.	Ether	Sulphuric ether, Ethyl ether.
	Ethyl acetate	Acetic ether.
	Ethyl nitrite	
	Ethyl bromide	Monobromethane.
2d. Chloroform and hydrate Group.	Chloroform	Trichlormethane.
	Chloral hydrate	Trichlorethidene glycol.
	Chlorotone	Aneson; Acetone chloroform; Trichlorpseudobutylalcohol.
	Chloral alcoholate	Trichlorethidene ethyl alcoholate.
3rd. Cocaine Group.	Alpha Eucaine	Benzoyl-methyl-tetra-methyl-gamma-oxy-piperidin-carboxylic-methyl ester.
	Beta Eucaine	Benzoyl-vinyl-diacetonalkamin hydrochloride.
4th. Opium-Morphine Group.	Heroin	Diacetyl morphine.
	Dionine	Ethyl morphine hydrochloride.
	Peronine	Benzyl morphine hydrochloride.
	Codeine	Methyl morphine.
5th. Acetanilide Group.	Acetanilide	Phenylacetamide; Antifebrine.
	Phenacetine	Para-acet-phenetidin; Acetphenetidin; Para-acet-amido-phenetol; Para-oxyethyl-acetanilide.
	Antipyrine	Analgesin; Anodynine; Parodyn; Phenazon; Phenyl-dimethyl-pyrazolon Pyrazine.
6th. Preservative, Sweetening and Flavoring Group.	Salicylic acid	Ortho-oxy-benzoic acid.
	Benzoic acid	
	Vanillin	Methyl-protocatechuic aldehyde.
	Saccharin	Benzosulphinide.

In the above groups it will be noticed that not only are the common name employed, but also the synonyms and structural formula names. The object of giving the latter, is simply to call attention to the fact that manufacturers are making frequent requests to be permitted to use some other words than those specifically enumerated in the act, for example, one manufacturer represents that a setting forth on the label of the fact that his

product contains opium, would be a financial loss and asks whether it would not be satisfactory to state on the label that this product contains a certain amount of Papaver somniferum. Other manufacturers request that they be permitted to use the word phenylacetamide, or the phrase "the monacetyl derivative of aniline," or the structural formula in place of the word acetanilide. If it were permitted to use other words than those given in the act for the ingredients specifically covered, there would soon be such a confusion of names and structural formula that it would be necessary to consult an expert organic chemist to decipher same.

It is held by some writers that it was absolutely unwarranted to include some of the chemicals and products enumerated in the rules and regulations, because, in many cases such articles are never used as habit producing drugs. In this connection it should be stated that this question was submitted to about twelve of the best pharmaceutical chemists, manufacturing and analytical, and while a few think that the public would be protected just as well without requiring a declaration on the label of the presence of certain ones, yet on the whole every one heard from thus far suggested additional products to be included. In other words the suggestions of these men indicate that instead of having included too many drugs, the list should be augmented. Our general correspondence confirms this attitude. It should furthermore be noted that it seems necessary to include certain chemicals in order to avoid technicalities; for example, it is held by one chemist that a certain chemical could not be considered a derivative of alcohol, because ethyl bromide is not enumerated as a derivative of alcohol in the regulations, and inasmuch as this chemical is employed directly in introducing the ethyl group into the product, it is necessary that this product be included as a derivative of alcohol. The contention that certain ingredients are not used as habit producing drugs, is not well taken. This claim is made for ether, which, as a matter of fact, however, is used to fortify beverages in order to render intoxication more rapid and complete, particularly is this the case where parties are addicted to the alcohol habit and the ordinary beverage does not appear to satisfy the appetite of the consumer.

The morphine group presents some interesting features. It is well known that both morphine and opium, and the disastrous re-

sults of same, have been widely exploited during the past few years, not only in the lay journals, but also to some extent in the public press. Many manufacturers deem it expedient to remove these words from their labels if possible because of this unfavorable notoriety. The result is that these ingredients have, in many instances, been replaced with other products which are not so well known to the public, for example, heroin, codeine and dionine have replaced morphine in a considerable number of cases. These chemicals are at present supposed not to produce as deleterious results on the human system as do opium and morphine even when used over extended periods, but what the future will bring forth by their promiscuous and indiscriminate use, is difficult at present even to conejcture. It is even now reported that where narcotic laws prohibit the indiscriminate sale of morphine and no restrictions whatever are placed upon the sale of codeine, that the latter product is being used in place of the former.

What has been said above in connection with the opium-morphine group applies equally to the acetanilide group. At the time the pure food and drugs act was passed there were approximately 500 headache and laxative preparations sold through the jobbing trade under various names which contained acetanilide. It is a significant fact that the acetanilide in many of these preparations has been replaced by acetphenetidin (phenacetine), and we are also informed, from various sections of the country, that antipyrine is being employed for the same purpose. Exactly why some of these changes have been made, is not clearly apparent, because none of the substitutes are as cheap as the acetanilide, although the price of each has been materially reduced within the past few years. This is due largely to the fact that the patents covering these chemicals have lapsed, and the price has fallen in the case of acetphenetidin (phenacetine) from $16.00 to $1.00 per pound, and antipyrine from about $22.00 to $2.40 per pound, both in bulk. The price of acetanilide in quantity at this writing is 25 cents per pound. Another probable reason for replacing acetanilide by acetphenetidin is because the latter is supposed to have a less deleterious effect upon the human system than the former, but this is at present an open question. No one has thus far ventured to give this as an excuse for using antipyrine, because it is a well known fact that the latter is the most

dangerous of these three medicinal agents. Two other potent factors, however, should be considered in this connection. These are: (first), that the deleterious effects of neither acetphenetidin nor antipyrine have been given any publicity and the public therefore has little knowledge of the meaning of the words acetphenetidin and antipyrine, should their presence be declared upon the label; (second), it was expected that both of these chemicals could be used indiscriminately in medicines without the necessity of declaring their presence upon the label. Acetphenetidin, however, according to the rules and regulations made under the pure food and drugs act, must be set forth on the label.

The use of harmful preservatives in food products is forbidden. The exact status, of the harmful nature, of certain preservatives is at present not definitely settled. Among the most conspicuous preservatives used during recent years are the synthetic chemicals known as salicylic acid and benzoic acid and their salts. The experimental results obtained in the Bureau of Chemistry in connection with salicylic acid and the salicylates have just been published in Bulletin 84, part 2, from which part of the general conclusions are herewith quoted:

> "There has been a general consensus of opinion among scientific men, including the medical profession, that salicylic acid and its compounds are very harmful, and the prejudice against this particular form of preservative is perhaps greater than against any other material used for preserving foods. This is due not only to the belief in the injurious character of salicylic acid but perhaps is especially due to the fact that it has in the past been so generally used as an antiseptic. That salicylic acid should be singled out especially for condemnation among preservatives does not seem to be justified by the data which are presented and discussed in this bulletin. That it is a harmful substance seems to be well established by the data taken as a whole, but it appears to be a harmful substance of less virulence than has been generally supposed. The addition of salicylic acid and salicylates to foods is therefore a process which is reprehensible in every respect, and leads to injury to the consumer, which, though in many cases not easily measured, must finally be productive of great harm."

Benzoic acid and the benzoates are by many considered less harmful than the salicylates. Whether or not this is correct remains to be established by future experiments and observations. This much, however, is certain that whenever it is possible, and

usually it is, food products should be prepared without the use of any questionable preservative.

Saccharin is generally employed as a sweetening agent and its use is largely of a deceptive character because the consumer usually believes that when he is eating a food product sweetened with this chemical, that the sweetening is due to some form of sugar. The use of saccharin as a sweetening agent is not only common in food products, but also in medical remedies. Saccharin is a most valuable agent for certain diseased conditions, but this does not justify its indiscriminate use. Inasmuch as deceptions and misrepresentations of all kinds are prohibited under the act, the presence of this chemical should be declared upon the label.

The synthetic production of vanillin undoubtedly was one of the greatest scientific achievements and triumphs of chemistry. Vanillin is a very valuable commodity. It is claimed by many that flavoring preparations made with vanillin as a basis possess distinct advantages over extracts made from the vanilla bean. There is no question whatever but that vanillin possesses certain merits not inherent in the vanilla bean, and it seems rather incomprehensible why manufacturers do not take advantage of this fact and sell vanillin preparations on their merits. Let not vanillin in disguise deprive extract of vanilla of its time honored reputation.

Mechanical and Engineering Section.

Railroad Management and Safety Devices.

By J. C. Irwin,

Superintendent of Construction, Electric Zone, New York Central & Hudson River Railroad Company.

When the subject "Railroad Management and Safety Devices" was assigned to me it appeared so broad that I was at first tempted to ask permission to confine myself to some one detail of this great field, but on second thought it seemed so aptly chosen as a basis for outlining the general subject of safety in railroad operation that it was accepted as offered with the idea of treating especially of the main features of signaling practice at the present time.

The appalling number of serious accidents that has occurred during the last few years and particularly during the last few months has attracted the attention of both the Government and the public at large to questions of railroad management more than ever before. While most of these accidents have occurred either on lines where there was no block system in operation or where the application of the system was so incomplete as to leave great chances for trouble, yet they have not been confined entirely to any one class of railroad, and the list will range from derailments and head-on collisions on lines of light traffic operated under a train order system alone through the various applications of telegraph block and controlled manual signals to occasional cases of rear-end collisions, on account of disregard of signals or derailments through defective equipment occurring under the operation of a highly developed automatic or controlled manual system with complete interlocking at switches.

The records show that by far the largest proportion of accidents is caused by defects in operation, the next by defects in equipment and lastly in track. The line between safe track and dangerous track is pretty clearly drawn. Trouble from equipment

is more likely to occur on account of difficulty in inspection and the temptation to avoid delay by passing equipment that should be held. In operation there is more occasion for quick decision and more chance for errors in judgment.

Practically all accidents are due to carelessness on the part of some one. A few are due to calamities such as are generally known as acts of Providence which no reasonable precaution would have prevented, but as a general thing, the prevention of carelessness means the prevention of accident. The work for the manager then, is partly a moral one, to build up an organization that is alert, active and cheerful, in which the tendency to carelessness will be minimized, and partly a mechanical one, to provide to the greatest possible extent, safety devices to make the right course clear and to act as a check on possible cases of forgetfulness or errors of judgment. Good signaling largely eliminates the chance for collisions; it renders possible the handling of a volume of traffic that would be absolutely out of the question without it; it furnishes the check on a large proportion of the opportunities for carelessness, but with the best of safety devices or without them, the question of good organization is paramount and no manager can afford to relax his vigilance and leave the result to the appliances. The motto "Eternal Vigilance is the Price of Safety" should be uppermost in the mind of the railroad man.

The safety devices will greatly assist but will not take the place of an alert organization, a definite line of responsibility and intelligent and continual supervision.

Good management therefore calls for good judgment in the selection and care of both the men and the machines, the animate and the inanimate elements of the service. If either is neglected at the expense of the other, the results will be poor in both, for a dissatisfied or disorganized personnel will not get the best results from the equipment, and on the other hand, poor equipment and supplies will gradually undermine the efficiency of the personnel.

A great deal has recently been said about the tremendous prosperity in this country and it is considered by many to be an unhealthy and inflated condition. It certainly is the cause, more or less directly, of the chief troubles in the operation of our railroads at the present time. The traffic has increased so rapidly that the efforts to increase facilities have not been able to keep up

with it. The increase in main track mileage has been almost nothing in comparison to the tremendous increase in the freight ton mileage.

The vast sums being spent for new passenger terminals and the electrification of suburban lines are no more than is necessary for the care of the rapid growth of the metropolitan suburban districts. The large expenditures for modern freight yards designed for the greatest economy in the classification of cars and the quickest possible movement through the yards have often resulted in little more than the furnishing of additional storage room for cars, either for the lack of better main line facilities over which to move them, or more often for the lack of warehouse room or of track facilities on the part of the industries to which they are consigned. Not only has this overwhelming increase in business shown itself in congested facilities but also in the difficulty in maintaining a well trained operating force. Although the rates of pay in all branches of the train service have been constantly increased, yet there is such a demand for skilled labor in all directions that in many instances it has been impossible to get enough good men to meet the exigencies of the service. It also seems that because money comes more easily, and for the reason that with the present labor agreements, promotion goes more by seniority and less by individual merit than formerly, there are men who take less pride in their positions and who are less likely to live up to that most important rule of railroading, "In all cases of doubt or uncertainty, the safe course must be taken and no risks run."

The function of the safety devices is to eliminate the doubt and to prevent trouble in case the safe course is not taken. Under the present congested conditions it is especially necessary to cover all the loopholes and to leave the operating officer as free as possible from reports or unnecessary office work so that his time may all be given to expert supervision and to keeping his eye open for chances for trouble before it occurs.

The public at large would probably be surprised to know how much of the time of railroad managers is taken up in the consideration of safety devices, in the earnest desire to select the best obtainable. It would also be surprised to know how many devices designed for safety, that look plausible in models or as laboratory experiments, are not only worthless but are actually

dangerous when applied under service in all kinds of weather and under the varied conditions that arise in actual operation. It requires an expert to select the good from the bad or the best from the next to best.

The general principles of interlocking of switches and signals and the operation of a block system have come to be pretty generally understood. At the time of the Electrical Exhibition of the Franklin Institute in Philadelphia in 1884 a committee of prominent members of the Institute including your Secretary was appointed to report on signaling apparatus. Their able report gives good information to-day on mechanical interlocking and the underlying principles of electrical signaling, including the use of the track circuit for controlling a signal circuit, so that when a train stands on the track section it short circuits the battery, de-energizing the relay and opening the circuit which holds a signal at "clear," causing it to go to "danger."

The principal improvements in recent years have been in the further application of power for operating both switches and signals. The Electro-pneumatic system in which the movements are operated by compressed air at 70-lb. pressure controlled by valves actuated by electricity and the Low Pressure Pneumatic system in which the movements are operated by compressed air at 20-lb. pressure, and controlled by valves operated by air at a still lower pressure, are in many large installations giving way to the All-Electric systems in which all movements are operated by electric power.

The latest complete record of the amount of railroad operated under the block system in this country is for January 1st, 1905. With about 214,000 miles of main line road, at that time about 40,000 miles were operated under some manual system and 5,000 miles under an automatic system. The remainder, most of which was single track, was operated under the train order system.*

In operating under a train order system alone the signals or

*Since the presentation of this paper reports made to the Interstate Commerce Commission in September, 1906, have been published. These show that of 143,615.8 miles of railroad covered by the reports, 48,743.2 miles was operated under some form of block signal. Of this amount 41,916.3 miles was covered by manual signals and 6,826.9 by automatic signals.—J. C. I.

order boards are used at telegraph stations merely to indicate to an engineman whether or not there are orders for him or to remind him of an order to be carried out. The orders given by telegraph are transmitted simultaneously to the offices at which they are to be delivered to the trains concerned in a movement and are directed to the conductor and engineman of those trains. The signal itself merely indicates "stop" or "proceed," but its operation is not connected with that of any signal ahead and the right to the track is conferred by train order.

In operating under a block system the road is divided up into a series of sections called "blocks," the limits of which are defined by fixed signals called "Block Signals," each signal by its indication controlling the use of the block ahead. By fixed signals are meant signals of fixed location indicating a condition affecting the movement of a train.

The block system is operated in one of three forms: The Telegraph, The Controlled Manual and the Automatic systems. In the telegraph block system the signals are operated by hand on information received by telegraph from the operators in the adjoining block stations. In this system the signalman has control of his signals at all times and can clear them at will, there being no mechanical check on him to prevent his giving a clear signal when the block ahead is occupied. By use of electric locks on signal levers, controlled from adjacent block stations, this may be developed into a controlled manual system.

In the controlled manual block system the signals are operated either mechanically or electrically by levers thrown by hand but so locked electrically that it is impossible for a signalman to give a clear signal for a train to proceed into a block without the cooperation of the signalman at the other end of the block. Communication between block stations is by bell code. When used in connection with continuous track circuit the Controlled Manual system gives the benefit of the presence of human intelligence and at the same time by means of electrical and mechanical devices puts it out of the power of the human element to give a clear signal in error. This system is particularly attractive on lines where there are switches and crossovers at frequent intervals requiring the presence of men to operate them.

In the Automatic block system no signalmen are employed, the signals being operated automatically by the passage of a train.

The power for the operation of the signals is supplied either by compressed air or gas or by electric motor, the control in every case being electric.

On account of the great preponderance of single track railroad in this country, one of the most active questions is, how to give the greatest protection on single track without "tying up the road." Automatic signals with continuous track circuit seem to be in most general favor, but there are some very satisfactory installations of the Train Staff system, an improvement on the Staff or Tablet system used in England. This system requires a block station at each end of the section protected, with a staff instrument in each, containing enough "Staffs" or small cylindrical pieces of metal to cover all possible movements of trains in one direction before any would pass in the other direction. Communication between the adjacent block stations is had by bell code, and the staff instruments are so interlocked that if a staff is taken out of an instrument at one end of the section no other can be taken out until it is placed in the instrument at the other end or replaced in the one from which it was taken. The system is operated in connection with a semaphore signal and a staff catcher and deliverer, so that the staff can be delivered to trains running at high speed, the signal being electrically controlled so that it can not give a clear indication unless the staff is in the staff deliverer ready for the train. No train orders are necessary, the right to the track being conferred by the staff. The device has given good results over congested sections of single track.

Every little while there is some new device brought up for giving an indication to an engineman in the cab of his engine, by means of light or bell. These devices are usually designed for use as adjuncts to the outside visual signals. As yet none of them seem to have gotten further than the trial stage.

The question of automatic stops is one that is continually assuming greater prominence mainly on account of the cases where enginemen have run past danger signals on lines with the best of signals maintained to the highest degree. In order for an automatic stop to be valuable, all equipment running over the line must be fitted with the stop device and it must be reliable under all conditions. The most suitable places for its application are those lines with dense traffic where the equipment is confined to a certain district. The Rapid Transit Subway in New York uses a

mechanical automatic stop consisting of a block rising above the rail when the signal is at danger, in a position to trip a valve in the train line of the air brake, stopping the train when the signal is at danger if it is not stopped by the motorman before reaching the signal.

A device known as the Kinsman system picks up current from an electrified track section and guard rail by means of a steel tongue or brush on the locomotive to make the contact, and uses the current to operate an electro magnet releasing a spring which operates a valve in the air brake train line, thus setting the brake, and in addition it uses the pressure of the air released from the train line to operate a piston around the throttle valve of the locomotive and shut off steam.

There will continually be greater opportunities for the application of such devices, when designed and installed in accordance with the best principles of signaling practice.

One of the important questions now under discussion is that of signal indications. Our day signals give their indications by positions and the night signals by color. After many years of settled practice with the downward position of the blade indicating clear, there is now a strong tendency to give the clear signal with the upward inclination, similar to the practice on German railroads. There is good reason for this change, for on account of the weight of the blade it has been necessary to heavily counterweight it in order to insure its remaining at danger in case of broken connections. Along with our other elements in signaling, the downward position of the blade was brought to us from England in the early days of railroading, and while it has been continually recognized by signal engineers that the upward position would be more rational, there has been no movement to make any change until the matter was recently acted upon by the Railroad Signal Association and the Signal Committees of some of the most prominent lines.

There is also diversity of practice in regard to the night indication. For many years white was uniformly the indication for safety or clear, with green for caution and red for danger. As the number of signals increased it came to be realized that in some places, particularly around a city, a multiplicity of white lights gave a chance for an engineman to mistake some other white light for his own clear signal, particularly if the light in his

signal happened to be out. There was also a chance for the breaking of a red lens in a danger signal to leave a white light indicating clear when the conditions called for a danger indication.

These conditions started the practice of using green for clear and an amber light for caution, leaving the red as a danger signal. Where white is still used for a clear indication, the practice is to make the red lens much heavier and tougher than was formerly done, eliminating the question of breakage.

It could not be within the scope of this paper to cover all of the valuable and interesting applications of signaling and its associated safety devices for the protection of traffic against obstructions or openings in the track, but as an example of the most highly developed signal practice at the present time, there may be given a description of the signal system now being installed in the "Electric Zone" covering the New York suburban district of the New York Central & Hudson River Railroad.

Besides being the largest signal contract ever awarded, this work represents an important advance in the art of signaling. Both block and interlocking work will be all-electric, operated by current taken from a power line running the whole length of the system. All track and signal circuits will be operated by alternating current; the only batteries to be used will be storage batteries for the operation of interlockings, which will be charged by an a.c-d.c. motor generator drawing current from the power line. In comparing proposals, the New York Central Railroad Company gave special consideration to safety and reliability and economy of operation, and also to quickness of delivery and erection, and the selection of this system was made only after the most systematic and careful deliberation.

At terminals and on short sections at interlockings, it was practicable to give up one of the rails of each track for signaling purposes, but for the greater part of the system it was of considerable advantage to the electric traction system to allow both rails of each track to be used for the return current.

The system offered by the General Railway Signal Company, and known as the "Young System," was adopted. Alternating current is used for track circuits in connection with reactance bonds, permitting the passage of the direct propulsion current freely through both of the running rails, while preventing the

flow of the alternating current which is used in signaling. This two-rail system was deemed best suited to the conditions.

Track plans showing the spacing and arrangement of all signals were prepared by the railroad company, and together with specifications were submitted to all the signal companies capable of handling the work. Separate bids were requested for the block signaling and the interlocking work.

To assist in finally deciding the system to be adopted, bids for block signaling were requested in eight different forms covering both normal clear and normal danger systems, all-electric and electro-pneumatic design, and either with one rail of each track given up for signaling purposes or with both rails left available for power return. Bidders were encouraged to make suggestions as to design and requirements of specifications, so that the specifications might not be considered to act as a restriction on the exercise of their best skill. In canvassing the proposals the Signal Committee of the New York Central Lines was called into consultation, and every feature was gone over in detail.

The work included by the contract covers what is known as the electric zone, extending from the Grand Central Station to Croton, on the Hudson Division, a distance of thirty-five miles, and from Mott Haven to White Plains, on the Harlem Division, a distance of nineteen miles. Throughout this distance there will be four main tracks, and the work includes about 3000 interlocking levers and 1400 track circuits, aggregating about 250 miles. The work to be undertaken at the present time covers only that portion of the road to be electrified this year, which carries the work from the Grand Central Station to High Bridge, on the Hudson Division, and to Wakefield, on the Harlem Division.

Power for operating the signal system will be taken from the two main power stations of the company at Port Morris and Yonkers, which deliver three-phase alternating current of 25 cycles and 11,000 volts, and from the various sub-stations which deliver direct current at 666 volts to the third rail for operating purposes. These sub-stations are also equipped with the transformers for the signal service, delivering alternating current at 3000 volts to the signal transmission line, which although extending the entire length of the district to be signaled, is cut half way between each pair of sub-stations, thus making that portion

of the line fed by each sub-station entirely independent of the adjoining one.

The apparatus in each sub-station is properly protected with automatic and hand-operated switches, and to insure operation, should the alternating current fail, d.c.-a.c. motor generators taking current from the storage battery system installed in each sub-station for use of traffic, will continue to feed the signal transmission line with alternating current, and the signal system will continue to work under all conditions under which traffic will be operated. A synchronizer is installed between the transformer and the motor-generator set.

The 3000-volt transmission line consists of No. 0 bare copper wire, carried on the pole line and in the conduits used for the main transmission system, and the signal bridges are equipped with extension brackets, with cross arms, for convenience in running wire lines to signals.

For the operation of signal circuits, signal motors, indicators, and signal lighting, the 3000-volt current is stepped down 50 volts, through transformers placed on signal bridges or transmission line poles. The secondary of the transformer is provided with a ground connection, formed by burying a 2-ft. x 3-ft. x 1-16-in. copper plate, to which is brazed a No. 4 B. & S. gage copper wire.

For track circuit operation the voltage depends on the length of track circuits, and varies from 1½ volts for circuits of 200 ft. to 8 volts for circuits of 5000 ft. The reduction from 50 volts to the track voltage is made by a transformer provided with four taps, which will permit of one type of transformer being used on all track circuits.

In laying out the block signaling plan, the length of the block was determined by the braking distance. For speeds not exceeding 45 miles per hour the blocks were made 1200 feet long; for speeds between 45 and 60 miles per hour, 2500 feet, and for speeds over 60 miles per hour, 3000 feet, the average length of the long blocks being about 3200 feet. All blocks have a full block overlap. A distant signal is provided for each home signal. On account of the density of traffic and the necessity for quick operation the clearing time of signals is limited to three seconds.

The track circuits are of three types. Where they are 500 feet or less in length, and where the drop in potential in the

length of the track circuits is not greater than 50 volts, the "one-rail" system is used, and one rail of the track is given up for signaling purposes. There being no direct current on the signal rail it is not necessary to use any reactance bonds.

On all track circuits over 500 ft. in length, the two-rail system is used, and both track rails are employed for the return of the direct power current. On all of these circuits it is necessary to use the reactance bonds, by which the connection is made around the insulated rail joints, permitting the direct current used in operating to pass, while impeding the alternating current used for track circuit work. The insulated rail joints are of the Weber pattern, with a steel angle plate on the inside.

On track circuits between 500 ft. and 1600 ft. in length the two-rail system is also used, and the reactance bonds consist of a copper bar 1 in. in cross section and 30 ft. long coiled in eight turns around an iron core.

It will be seen that the block sections are of two types, the one-rail and the two-rail systems. In the former the propulsion current flows along the continuous rail, and in the event of a defect in the continuous rail, this current must avail itself of the conductivity of adjacent tracks, through the cross bonding.

In sections of the two-rail system each of the traffic rails of a track forms separate and independent conductors, so that if one rail is interrupted, the other would act as a return conductor, even if there were no cross-bonding to adjacent tracks.

The use of two styles of bonding was determined by the cross-bonding for the electric traction system. The Engineering Department of the railroad company determined that the distance between such cross-bonds should not exceed 1600 ft. For blocks that are 1600 ft. or less in length the type of bond, allowing cross-bonding at the ends of the track sections, was best suited to the conditions. For track circuits over 1600 ft. in length, where a cross-bond between one rail of each track was required every 1600 ft., the ironless reactance bond is the least expensive and the one to be used.

All of the reactance bonds are enclosed in water-tight cast-iron boxes, set on foundations, and the boxes are filled with oil to carry off the heat generated. The bond is designed to permit the continuous passage of 3000 amperes for each rail of the track without injurious heating. The casing of the box is made to cover

the terminals and connections to the rail to keep them from being tampered with.

The track relay is of the induction motor type with two field coils. One coil is energized by the 50-volt signal operating current which gives the greater part of the energy required to magnetize the fields and armature. The other coil is energized by the current from the track rails, and this current need only be strong enough to give sufficient magnetism to rotate the armature. The armature revolves through an angle of 37½ deg., during which movement the contacts are separated through 23½ deg., and made up through 14 deg., thus giving a good rubbing contact. Especially hard carbon is used for the fixed point of the contact, while the moving point is of platinum. As the controlled current is an alternating one, there is little sparking, although currents of from 2 to 3 amps. are used.

The box containing the track relay and transformer and the grid resistance has a plug in which an electric light can be cut in for use in night inspection.

The signals are to be of the General Railway Signal Company's motor-operated type, with mechanism placed in the base of the signal mast, and worked by a single-phase alternating motor of ¼ hp. using current at 50 volts. The slot mechanism is exceedingly simple, and under alternating current operation is very quick in releasing.

The signals are of the 60-deg. two-position type, using New York Central standard spectacles and blades, which impose on the signal motor a load equal to the lifting of a 17-lb. weight, at a distance of 4 ft. from the center of the shaft. With this load the motor will clear the signal in from two to three seconds. The New York Central Standard signal blades have square ends for home signals at interlockings, and pointed end blades on automatic home-block signals. The signal lamps are of 4 cp, working on a 50-volt circuit, and are connected in parallel with a fuse cut out, to allow any lamp to be disconnected, without affecting other lamps supplied on the same circuit. The filament of the lamp is wound in a small circle, to bring the point of maximum illumination within the focus of the lens.

The signals to be used in the Park Avenue tunnel will consist of lights only, without any moving parts whatever. Electric lights will be arranged in a box behind lenses of proper color, and

the current for the lamps will be directly controlled by the relay contact. Lamps giving the proper color for the stop or caution indication will be lighted when the track relay contact is closed.

With this installation the colors used by the New York Central for the night signal indication will be changed in the electric zone, and instead of using white for proceed and green for caution, the system of using green for proceed and yellow for caution will be used for the first time on this line.

The interlockings are of the standard type, manufactured by the General Railway Signal Company. Direct current furnished from storage batteries is used to operate the switch movement and signals. As usual with this type of apparatus the indication is given by the current formed by the motor, which on completing its stroke at the signal or switch movement, is changed to a generator and gives sufficient current to release the lock of the lever of the machine.

The current to change these storage batteries will be obtained from an a.c-d.c. motor generator set, taking current from a transformer fed from the 3000-volt signal transmission line and furnishing current of 150 volts. The storage battery consists of fifty-five cells of capacity varying from 80 amp-hours to 320 amp-hours, according to the number of daily lever movements to be made. The average time between charging will be four days. The motor generators with switchboards will be placed in the basement of tower buildings and a separate battery-house will be provided to keep the fumes of the batteries away from the signalmen and the apparatus in the towers.

The interlocking machines are of the usual type made by the General Railway Signal Company, and are provided with a latch for each lever to require a definite action on the part of the operator to change the position of the lever. The lever handles are colored according to their functions. There will be a separate lever for each high signal arm and no selectors will be used.

The interlocking signals will be of the General Railway Signal Company type with dynamic indication current return. These signals, where slotted, will return to the stop position when the current through the slot magnet is open, but the return indication from the signal motor is not received at the lever until the lever is restored to the normal position. The operating circuits for the signals are run through controllers on all facing switches in the

main line, insuring that the switches are properly set before the signals can be cleared.

Block signals on the same mast with distant signals are controlled by a lever in the machine requiring the block signal to be changed to the stop position before a signal can be cleared for a reverse movement on the main line.

The advance signals for each track, although operating as automatic block signals, are controlled from the interlocking and are provided with a square end blade to enable the signal man to hold a train, if it is desired to do so.

Approach locking will be provided for all main-line switches. This locking becomes effective when a train has reached a point at least one mile in the rear of the distant signal.

To permit the signal man to change the route for a train, in case of a mistake in setting it up, a mechanical screw release is provided. This will allow the release of the lever and changing the route on the expiration of a time interval of $1\frac{1}{2}$ minutes after the signals have been returned to the stop position. A counter reading to five figures is to be placed on all high signals to register the number of movements.

The movement to be used to operate the switches is of an entirely new type. With the small clearance under the third-rail contact shoe, a mechanism that will not project above the top of the running rail is absolutely necessary. This movement is enclosed in a neat casing with the gear and escapement crank horizontally arranged. The reversible pole changer and indication switchbox are also enclosed in the casing with the switch mechanism, protecting these parts and giving an exceedingly neat appearance to the apparatus.

The movement is fitted with an improved locking device which, in the case of the plunger catching on the locking rod, as it will do if the switch does not lock up properly, will release the plunger, allowing it to stop while the main part of the movement completes its stroke. The arrangement prevents the motor from forcing the plunger through the lock rod in case it should not have come to the proper position.

The type of dwarf signal to be used is a new one, the signal arm being moved to a motor mechanism arranged horizontally at the base of the post. With this apparatus the indication will be returned to the lever by the current generated by the motor in-

stead of by battery current, as is required with a solenoid mechanism.

In this installation the use of detector bars is practically abolished, a few only being used on the outside rail on sharp curves. Short electric track circuits are provided in their place, effecting the locking of the switches during train movements by controlling the locks on the switch levers. The use of these short-track circuits with the controlling wires to the interlocking machine, makes possible at small expense the use in the interlocking tower of illuminated track indicator. It will consist of a track plan of the interlocking painted on a piece of ground glass with the track circuit sections divided on the back of the glass into separate compartments in which are a red and a white electric light. When the track section is occupied a red light will be shown on the indicator plan, and when unoccupied a white light will be shown.

In places like the Grand Central Terminal, where the tracks will be entirely roofed over, it will not be possible for the signal man to observe the movements of many of the trains; and an indicator of this kind is an absolute necessity to enable him to keep in touch with the situation. As in the Park Avenue tunnel, the signals in the Grand Central Station interlocking will be shown entirely by lights without any blades or moving parts. In this interlocking work, however, the lever for the signal completes the circuit for the lamps to give the proper color for the indication required.

This detailed description of an important installation gives an idea of the progress in signaling practice in connection with electric traction. The main cry of the country, however, is for the extension of the block system and its allied safety devices over lines not properly protected and wide-awake supervision both for maintenance and operation that will get the best results out of the apparatus provided.

Book Notices.

PUBLICATIONS RECEIVED.

Michigan College of Mines. Year Book, 1905-1906. 131 pages, 12mo. Views at the Michigan College of Mines, Supplement to the College Year Book. Twenty-five illustrations, showing the exterior and interior of the college buildings and the students at work. Oblong, 24mo. Houghton. Mich. The College, 1906.

Transcœrsal-Dampfturbinen für elastiche Kraftnittel: Wasserdampf, Luft. schweflige Säure, Kraftgas u. dgl. von A. Patschke, Ingenieur in Mülheim a d. Ruhr. Ed. 1. 73 pages, plates, 8vo. Mülheim, Max Röder, 1904. Paper. Price, 2.50 marks.

Index to the Transactions and Journal of the New England Water Works Association, to December, 1903, inclusive. 115 pages, 8vo. Boston. New England Water Works Association, n. d.

U. S. Department of Agriculture, Weather Bureau, Bulletin Q. Climatology of the United States, by Alfred Judson Henry, Professor of Meteorology. Prepared under the direction of Willis L. Moore, Chief U. S. Weather Bureau. 1012 pages, maps, Q. Washington. Government Printing Office, 1906.

Sections.

Electrical Section.—*Stated Meeting* held Thursday, November 22d, at 8 P.M., Mr. Thomas Spencer in the chair. Present, twelve members and visitors. The President introduced Mr. James B. Hoge, of Cleveland, President of the International Independent Telephone Association, who presented an interesting communication on the Development of Independent Telephone Lines. The paper was discussed by Messrs E. Alex. Scott, W. C. L. Eglin, H. F. Colvin and the author.

The thanks of the meeting were voted to the speaker of the evening, and the meeting was adjourned.

Wm. H. Wahl, *Sec'y pro tem.*

Stated Meeting, held Thursday, January 24, 8 P.M., Mr. Spencer in the chair. Present, forty-eight members and visitors. Mr. H. I. Mauger. General Electric Company, gave an informal address on the subject of "Electricity in the Home," which he illustrated by the exhibition of a considerable outfit of electric heating and cooking appliances and with a collection of lantern photographs exhibiting views of buildings completely equipped with fixtures and appliances for utilizing electricity for domestic purposes.

The speaker expressed his belief that within a few years the installation of an electrical equipment in new dwellings would become universal.

The subject was freely discussed. Adjourned.

Wm. H. Wahl, *Sec'y pro tem.*

Section of Physics and Chemistry.—A meeting of this Section was held on Thursday, January 10th, at 8 o'clock P.M. The President, Dr. Robt. H. Bradbury, in the chair., Present, thirty members and visitors.

The President introduced Mr. Lyman F. Kebler, chief of the Drug Laboratory, U. S. Dept of Agriculture, who read a paper on "Synthetic Chemicals." The paper was freely discussed by Dr. Edward Goldsmith, Prof. Remington, Mr. M. I. Wilbert and the author.

A vote of thanks was passed to the speaker of the evening.

Adjourned.

Edward A. Partridge, *Sec'y*

The First Atlantic Telegraph Cable Fleet.

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THE FRANKLIN INSTITUTE.

The First Atlantic Telegraph Cable.

(A Supplementary Note.)

BY JOHN MULLALY.

The illustration of the Atlantic Telegraph Squadron shown in accompanying picture, which was composed of the four warships employed in the laying of the great ocean cable, is a minute reproduction of a large lithographic print published under the patronage of the Commanders and officers of the vessels and was dedicated by the artist to Hon. George M. Dallas, at that time (1857) United States Envoy Extraordinary and Minister Plenipotentiary to Great Britain.

The Squadron consisted of the U. S. Steam Frigate Niagara and the British line-of-battle Ship Agamemnon, both vessels having been selected not only as the largest men-of-war in the respective navies of the two nations, but because they were also

the best adapted otherwise for the important undertaking in which they were to be engaged. They were accompanied by two smaller vessels, the U. S. Frigate Susquehanna, acting as the escort of the Niagara, and the British Frigate Leopard, doing similar duty for the Agamemnon.

The Niagara, as shown in the engraving, had a capacity of at least three thousand five hundred tons, and the Agamemnon had about equal register. The two ships were built on entirely different models, the first having been designed on the plan and lines of the clipper ship, and the second on the old style of the ninety-six gun ship of the line. In point of speed there was no comparison, the American vessel being much the faster of the two, a fact, however, which did not detract from the usefulness of the Agamemnon in the work of cable laying, which rarely exceeded a speed of seven or eight miles an hour.

In the preparation of the ships for the work to which they were assigned it was found necessary not only to strengthen the decks on which the Cable was to be coiled, but to make radical changes for its proper distribution. Large circles, fenced around with heavy planks to the height of four or five feet and shored up with massive beams, formed the receptacle in which the Cable was laid in successive layers around a central cone. Thus the Cable on the Niagara was, with a due regard to the "trimming" of the ship, divided into seven parts, or sections, three of which were placed on the main deck, two on the second deck and the balance in the hold.

The armament of the ship had been removed and every available foot of space that was required for the machinery and appliances in the submersion of the great submarine line was appropriated and even the sleeping quarters of the officers in the Ward Room were invaded. The whole internal aspect of the Niagara, in all its decks, was changed. The huge warship, (huge for that day) which had been armed at every point with great guns and other weapons of destruction, was transformed into an agent of peace and industry and science for the binding together of nations in commercial intercourse and friendly relations. The ponderous cannon had been unshipped and relegated to the forts and arsenals on land, and the magazines were emptied of their tons of explosives and deadly missiles, while the paying-out machinery, over which the Cable was carried into the depths of the ocean,

two-and-a-half miles beneath the surface, occupied more than three-fourths of the main deck. At the stern of the Niagara was erected the grooved wheel over which the Cable passed in its descent to its resting place on the Telegraph Plateau, which extended at a uniform depth between Ireland and Newfoundland, the two termini, or points of connection of the Atlantic Telegraph.

While it is true that the two warships which had been selected on account of their carrying capacity were otherwise unfitted for the work of cable laying, it is very doubtful if, in view of the magnitude of the enterprise and the amount of capital required, it would have been accomplished but for the international cooperation extended by the two governments and the timely, effective and substantial aid thus afforded. Had the undertaking depended solely on its merits as a commercial project its accomplishment in the face of the incredulity, and even suspicion in some quarters with which it was regarded, it would most probably have been postponed for another generation.

In view of all the circumstances attending the early history of the Atlantic Telegraph, the failures and losses and disappointments by which the first trials were beset, though finally crowned with a success that proved its practicability, the illustration of the united ships of the two nations engaged in the solution of one of the greatest of scientific problems possesses more than ordinary historical interest.

Tasmania, like Utah, has its smelter-smoke question, a deputation of members of the town board of Queenstown having recently taken up the question of preventing or minimizing the escape of sulphurous gases from the Mt. Lyell furnaces. Mr. Sticht held out very little hope of an amelioration of the difficulty. This is one of the great metallurgical problems of the day, being of far more consequence now than formerly, because of the immensely greater volumes of gas that are discharged by modern smelting works, which have been greatly increased in size. The problem is engaging the attention of the ablest metallurgists in several parts of the world.—*Eng. and Min. Journal.*

According to the Queensland *Government Mining Journal* a discovery of tin is reported from Waratah, Tasmania. The lode is said to be twelve feet wide and thirty per cent. ore has been taken out.

BOILER CONSTRUCTION AND RATING.

Students and philosophers frequently speak of cycles in connection with subjects under their attention. Cycles occur in trade as in other realms. It is only a few years since the manufacturers of house heating boilers departed from the egg shell or beehive type of construction to those which presented in the combustion chamber additional surface for the absorption of the heat radiated from the fire, and also impinged upon it by the flames and the products of combustion. It is not so far back when house heating boilers were made of two dome shaped castings of different dimensions, so that when one was set over the other there existed a space between them through which water could be heated and circulated or steam generated. The bottom connection of these two castings was sometimes made tight all around the outer circumference by means of a rust joint. Boilers of this construction, while efficient in heating large quantities of water, as in greenhouse heating, lacked important qualifications for economy when used for heating residences, and the evolution in boiler production resulted in constructions which presented additional surface exposed to the fire and gases, and which provided for a sufficient travel of the products of combustion before their liberation to the chimney to absorb as much of the heat they carried as practicable.

This led to designs which were radically different from the original egg shell boiler, with its direct draft and arrangement, presenting only that surface exposed by the under side of the egg shell. This departure had the effect of causing the introduction into the egg shell construction of surfaces arranged in the form of baffle plates to secure the longer fire travel and secure some economy. In the main the trend has been away from the old bee hive construction, but at various times some manufacturer has taken the downward and backward step, though the latest productions have proved more efficient and more economical and more satisfactory to the final buyer than those which rendered service to the final buyer only at the expense of extravagant consumption in fuel and frequent firing.

The evolution of the boiler from the egg shell type to the best type of horizontal sectional boilers having a long fire travel and staggered flues, and to the vertical sectional boilers of the return flue type, has progressed steadily until the better types are quite generally made and used. These steps have been attended, however, with many divergings. Frequently those who were better salesmen than engineers have been able to sell their productions of the old inferior types on the claims of equal capacity and lower price. This has led to some annoyance to those buyers of boilers who were not thoroughly capable of determining capacities. Notwithstanding the ratings given by manufacturers to their constructions, competent engineers frequently depend upon their own calculations regarding the power possessed by the grate surface, the fire surface and the flue surface exposed.—*The Metal Worker.*

Mechanical and Engineering Section.

(Stated Meeting held Thursday, March 7th, 1907.)

The Modern Locomotive.

Mr. Paul T. Warner.

It can truly be said that the steam locomotive has reached a crucial point in its development. He would be a bold prophet who would venture to say that the limit of capacity has been reached. If, however, future locomotives are to be made more powerful than the largest now building, it is probable that some radical changes in design must be made in order that such an end may be accomplished. With the enormous amount of freight traffic handled at the present day, there is a constant demand for locomotives of increased tractive power, in order that the tonnage may be removed with a fair degree of economy. The requirements of modern passenger service necessitate the hauling of express trains which are frequently as heavy as were the freight trains of a few years ago. This fact, coupled with the higher speeds of to-day, has necessitated the construction of locomotives having exceptional steaming capacity; and the demands made upon the engines employed in this class of service are daily becoming more exacting. The electric locomotive is now entering the field, and with its increased possibility for higher capacity, is receiving great attention from all who are interested in the motive power problem. The day of the steam locomotive has not yet come to an end, but the law of the survival of the fittest must eventually decide the question; and in certain localities where special conditions exist, the electric locomotive has already demonstrated its superiority. This fact, however, is only assisting in the further development of the steam locomotive; and the problem of how its efficiency may be improved, is receiving the

closest attention of motive power officials and locomotive builders.

Concentration of power is essential in order to meet conditions as they exist in the mechanical world to-day; and the modern locomotive is a striking illustration of the fact. The locomotives exhibited at the St. Louis Exposition of 1904 showed an average increase in weight over those shown at Chicago in 1893, amounting to more than 50 per cent. So rapid has been the growth in size and tractive power, that the locomotive has set the pace for improvement in practically all other branches of railway service. Its introduction has compelled the use of stronger bridges, heavier track construction and improved shop and roundhouse facilities. The great weight of modern freight trains, made possible by the high tractive power of the locomotives employed, practically necessitates the use of freight rolling stock equipped with steel underframes, improved draft gear, and automatic couplers and air brakes. On many roads the largest locomotives are still in advance of the facilities provided for maintaining and repairing them. In handling freight traffic, difficulties are frequently experienced because of the continued use of old cars having draft gear inadequate to stand the shocks and stresses to which it is subjected. The successful firing of the largest engines presents another problem, as it is almost beyond the ability of the fireman to handle the fuel required. The automatic stoker promises relief in this direction, and its more general use may be expected with the further growth of the locomotive.

As engines have increased in size, the number of types in use has been multiplied. Formerly the well known eight-wheel, or American type of locomotive, handled practically all the passenger and a large proportion of the freight traffic of the country. It now, however, has become inadequate, and new types have been developed to meet the changed conditions. In fast passenger service, for example, the ability of the locomotive to meet requirements depends largely upon the maximum horsepower which can be developed. The boiler then becomes the limiting factor, and its capacity must be large in proportion to the tractive power of the engine. Opposed to this class of work is heavy freight service, requiring a locomotive having great tractive power and consequently ample weight on the driving

wheels. As this tractive power is developed at slow speeds, the boiler power is not proportionately as great as in the fast passenger locomotive. Between these two extremes may be placed fast freight and heavy medium speed passenger service. This work necessitates locomotives having ample weight on the driving wheels and high steaming capacity, and types of engines, which are satisfactorily meeting these conditions, have been developed. In addition there are designs for switching and local service, heavy mountain pusher service, and other special work.

From what has been said it is evident that a consideration of the "Modern Locomotive" must deal with those peculiar features which have made possible the meeting of present day demands. The source of power, in the steam locomotive, is its boiler; and therefore the first requisite in a high powered engine, is ample steaming capacity. This necessitates a grate of sufficient size to burn the required fuel at an economical rate; a fire box of ample volume and approved form, and sufficient heating surface to transmit the heat of combustion to the water, without undue waste at the stack. Provision for good circulation is also a necessity; as well as an arrangement in the front end, or smoke box, that will equalize the draft through the tubes, and result in the most efficient draft action on the fire.

Bituminous coal-burning locomotives of ten or fifteen years ago, such as were exhibited at the Columbian Exposition of 1893, were almost invariably constructed with fairly deep fire boxes having the grate placed between the driving wheels. The width of the fire box was thus strictly limited. As locomotives increased in size, the grate was lengthened, until successful firing became difficult, and in the largest engines, almost impossible. The time was clearly at hand when increased grate area and boiler power were essential; and it became evident that a radical change of design, especially in the case of fast passenger locomotives, was necessary in order to secure the end desired.

In 1895 the Baldwin Locomotive Works built for the Atlantic Coast Line, an engine which was the forerunner of the type now largely used in high speed service. This locomotive had a four-wheeled leading truck and two pairs of driving wheels, which were placed as far forward as possible. The pistons were connected to the second pair. The fire box was placed behind the rear driving axle, thus permitting it to be made of ample depth

and volume. To carry the resulting overhang, a pair of trailing wheels was introduced. This locomotive, to which the name "Atlantic" type was given, was built to fulfill a difficult guarantee, and proved successful. A large number of similar engines followed, and the type was soon adopted by other builders in this country and abroad.

The next step in the development of the "Atlantic" type locomotive was to provide a wide fire box for burning bituminous coal. The grate was placed entirely behind the driving wheels, its width thus being limited only by the loading gauge, while ample depth of furnace was readily secured. Thus there was developed the type of locomotive which to-day is working a large portion of the fastest traffic, not only in this country, but also in Great Britain and on the Continent of Europe.

The addition of the trailing wheel is essential in locomotives having large driving wheels combined with deep wide fire boxes, and a number of types possessing these features have been developed during the past six years. The accompanying diagram shows these classes in outline, as compared with corresponding types which preceded them. The diagrams show clearly how the wheel arrangements have been modified to suit the boiler requirements. The changes noticed have resulted in providing the locomotive with increased boiler capacity in proportion to the weight carried by the driving wheels—in other words, to the tractive power. Thus the eight wheeled engine, formerly so generally used in high speed service, carries about 66% of its total weight on the driving wheels; while in the modern "Atlantic" type, the proportion is about 55%. Assuming, therefore, that an eight-wheel and an "Atlantic" type engine carry the same weight on their driving wheels, the total weight of the "Atlantic" type will be about 20% in excess of the eight-wheeler. This additional weight is utilized principally in providing a larger boiler. Hence while the tractive powers of the two engines at slow speeds will be the same, the maximum horse-power which can be developed in the "Atlantic" type will be in excess of that of the eight-wheel engine. It is for this reason that in such severe service as that between Camden and Atlantic City, for example, "Atlantic" type engines are able to maintain the schedules required where the eight-wheel engines have proved inadequate.

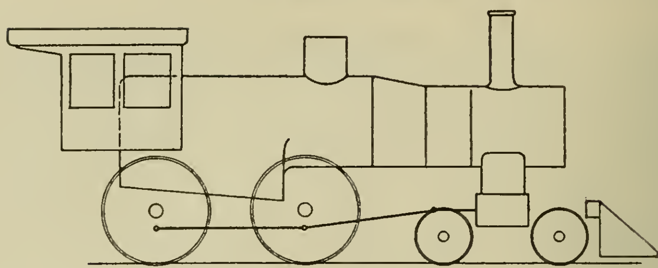
The "Pacific" type locomotive stands next in the series, and

has been developed from the ten-wheel type. It has the same characteristics, in many respects, as the "Atlantic" type, and is suitable where the trains are so heavy that the tractive power required necessitates the use of three pairs of driving wheels. The "Pacific" type represents the most powerful class of passenger locomotive thus far produced. With the wheel arrangement and boiler design employed, the tubes are long—frequently twenty or twenty-one feet. Ample heating surface is thus provided, and the fire box can be made of most liberal dimensions. Where a passenger locomotive having great tractive power and high steaming capacity is desired, the "Pacific" type is frequently selected.

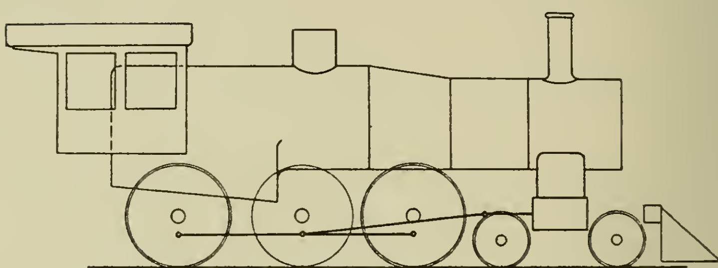
The "Prairie" type, which stands next in the series, is a development of the well known "Mogul" locomotive, and is admirably adapted to fast freight service, where an exceptionally powerful boiler is wanted in combination with three pairs of driving wheels. The tubes are somewhat shorter than in a Pacific type engine having the same size wheels and driving wheel base. The front end of the engine is supported by the fulcrum of an equalizing beam placed under the cylinder saddle, and this arrangement is liable to result in rather unsteady riding at high speeds; hence for fast service, the "Pacific" type is usually regarded as preferable where a six-coupled engine is required. On some roads, however, the "Prairie" type is successfully employed in fast passenger service. Engines of this type were first used in 1900 by the Chicago, Burlington and Quincy Railway in the Middle West, whence the name was derived.

For many years the "Consolidation" type has been (and still is) regarded as the most suitable for heavy freight service. With the moderate size driving wheels usually employed, a wide fire box can be placed over them without difficulty. If, however, an exceptional depth of furnace is needed, as is desirable for burning lignite, for example, the "Mikado" type is used to advantage. This class took its name from a number of locomotives which were shipped to Japan by the Baldwin Locomotive Works about ten years ago.

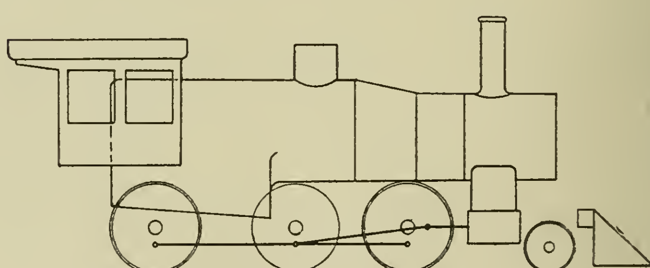
There are also one or two special types which have come into service during recent years, examples of which will shortly be presented. It must not be supposed, however, that the American ten-wheel and Mogul types have become obsolete. They are still



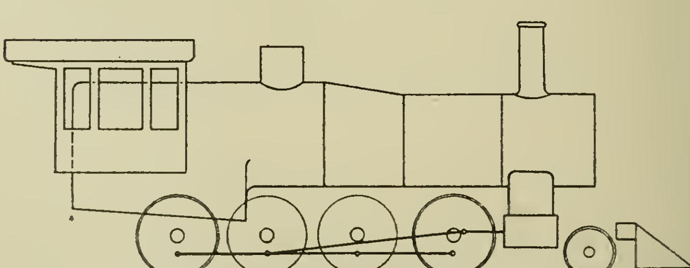
American Type.



Ten-Wheel Type.

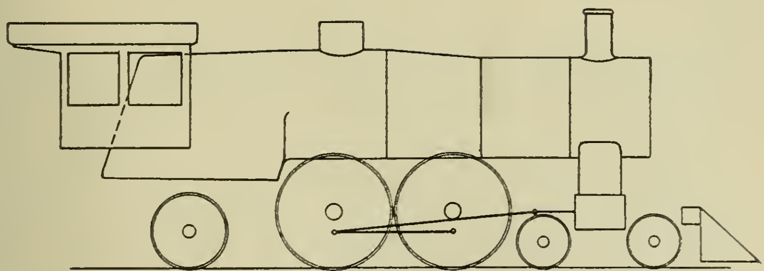


Mogul Type.

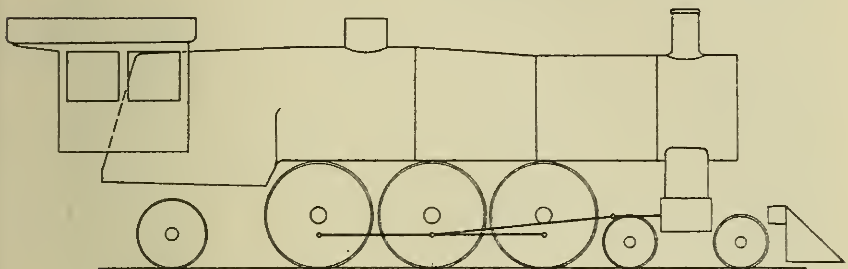


Consolidation Type.

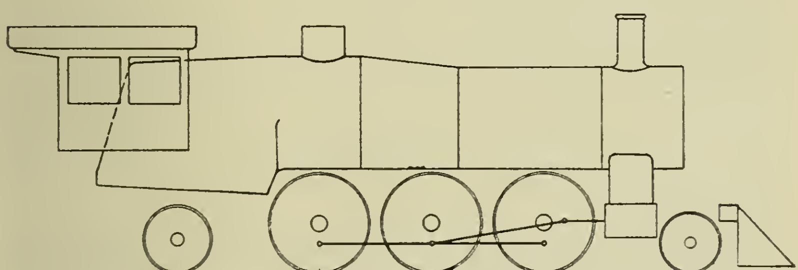
Types of the American Locomotive



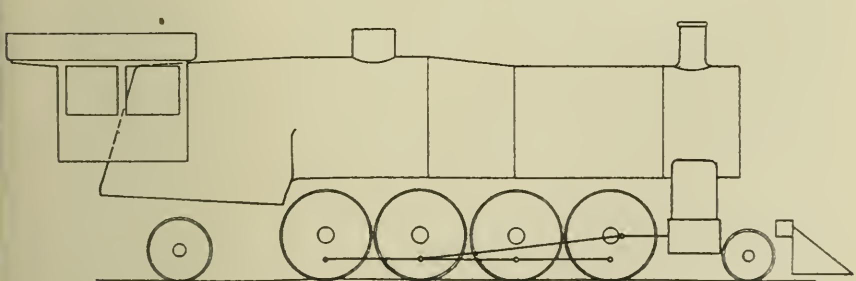
Atlantic Type.



Pacific Type.



Prairie Type.



Mikado Type.

Types of the American Locomotive

extensively used, and may be fitted with wide fire boxes if the wheel diameters are sufficiently moderate; but for the most severe service, where great boiler power is necessary, trailing wheels are usually required.

As has been indicated, the wide fire box was adopted in order to provide sufficient grate area, and at the same time keep the length of the furnace within reasonable limits. Ample heating surface can be secured in a boiler having a narrow fire box, but the ratio of grate area to heating surface is then so high that an excessive rate of combustion per square foot of grate must be maintained. Furthermore, in a narrow fire box boiler of large diameter, the side sheets of the fire box must curve outward at a sharp angle in order to meet the shell. It is thus difficult to secure a favorable disposition of the stay bolts, while in order to obtain the maximum width of grate possible, there is a tendency to cramp the water legs and so impede circulation. With the wide fire box, these difficulties can be avoided. The water legs are nearly vertical, and can be made of ample width without restricting the grate area.

The effort to secure improved circulation is noticeable in recent boiler designs, as is evidenced by the use of wider water spaces and more liberal tube spacing. It is found that better service is secured by spacing the tubes farther apart, even though the heating surface is thereby reduced; and the practice of filling a boiler as full of tubes as possible, in order to secure the maximum number of square feet of heating surface, is now being abandoned.

Regarding the driving mechanism, the most conspicuous development, during recent years, is found in the balanced engine. In the ordinary two cylinder locomotive, excess weights are placed in the driving wheel counterbalances, to neutralize the disturbing effects of the reciprocating parts. The centrifugal effects of these weights, when running, results in a periodic increase of the wheel pressure on the rail, which may become excessive at high speeds. With the advent of the heavy locomotive the problem of the counterbalance has become particularly difficult of satisfactory solution. The most logical method of avoiding the so-called hammer blow is to use four cylinders, placing the two cranks on the same side of the engine 180° apart, so that the reciprocating weights oppose one another in movement,

and their disturbing effects are thus neutralized. Compound cylinders can be readily applied to a locomotive of this type, and the economic advantages due to double expansion of the steam can thus be realized.

Balanced compound locomotives have been used abroad for some years, especially in France, where they are employed on practically all the high speed trains. European designs have generally been regarded as too complicated for successful use in this country, but in 1902 the Baldwin Locomotive Works introduced a simplified form of balanced compound locomotive which is adapted to American conditions, and has given good results in service.

In the Baldwin engine, the cylinders are placed in line across the locomotive, the high pressure being between the frames, and the low pressure outside. A single piston valve controls the steam distribution to each pair of cylinders, which, with their common steam chest, are cast in one piece with half the saddle. Wherever possible, the leading pair of driving wheels is moved back sufficiently to enable it to be driven by the inside (high pressure) cylinders, and is then provided with a cranked axle. The outside cylinders are coupled to either the first or second pair of driving wheels, as preferred. When the latter arrangement is adopted, the outside guides and piston rods are lengthened, in order to keep the length of the outside main rods within reasonable limits.

The crank axle has frequently been regarded as a weak point in an engine of this type, but with the materials and methods of manufacture now available this member has been so perfected that little or no trouble is experienced in service. The latest form of axle used by the Baldwin Locomotive Works is built up and composed of seven pieces, which are pressed together in a hydraulic machine. The central member is of cast steel. This form of axle, while heavier than the solid forged type, is less expensive to make, and the forged parts can be thoroughly worked and specially adapted to the service they have to perform. Should any part require renewal, it can be replaced without discarding the entire axle.

Owing to the fact that, in this type of locomotive, the piston thrusts on the same side of the engine oppose one another, the frame stresses are greatly reduced. It is found in service that

these engines are practically immuned from frame breakage. This is an important point, as it does away with an annoying feature which not infrequently exists in large two-cylinder locomotives.

The balanced compound locomotive, when properly handled and maintained, has proved highly efficient and economical in service. In July, 1904, the Chicago, Burlington and Quincy Railroad carried out a series of tests with engine No. 2700, a balanced compound Atlantic type locomotive, and three single expansion engines. The tests were run in fast passenger service, over a difficult section of the road, in which the total rise is 2044 feet in a distance of 142.9 miles. The compound developed an average indicated horse-power hour on 24.37 pounds of water, as against 30.10 pounds for the most economical single expansion engine tested. That is, given two locomotives, one a compound and the other a single expansion, both having the same sized boiler, the compound can develop 20% more horse-power than the other. Locomotive No. 2700 proved its ability to make good this claim, and on one occasion made time with a train of twelve cars, weighing with the engine and tender 719 tons. None of the single expansion locomotives was able to equal this performance. Subsequent tests carried out on this road have substantiated these results.

The American Locomotive Company has also produced a balanced compound locomotive, to the designs of Mr. F. J. Cole. In this engine the high pressure cylinders, which are located between the frames, are placed in advance of the low pressure, which are outside the frames. The high pressure pistons are connected to the leading axle, which is cranked, while the low pressure are connected outside, to the second pair of driving wheels. With this arrangement, connecting rods of approximately equal length and weight are secured. This system of compounding has been applied to a number of locomotives of both the Atlantic and Pacific types.

The introduction, during the past two years, of the Walschaerts valve gear on a large number of American locomotives, is a matter which deserves notice. For many years the use of the Stephenson link motion on locomotives was, in this country, practically universal. As long as engines were of moderate size, it gave satisfaction; but with the introduction of the modern

heavy locomotive, certain difficulties were encountered. Axles have grown to such a size, that the diameter of the eccentrics must be considerable in order to get the required throw. This increases the velocity of the rubbing surfaces, tending to result in heating. The parts of the gear become heavy and cumbersome, and their inaccessible location renders proper inspection and lubrication difficult. In order to overcome these disadvantages, a number of roads have recently introduced the Walschaerts motion. This gear, which is of the radial type, and named after its inventor, was patented in Belgium in 1844, and is extensively used on the Continent of Europe. It is placed entirely outside the driving wheels, and all parts are readily accessible. The principal motion is derived from a return crank, secured to one of the crank pins. This crank actuates a link, which is trunnioned at its middle point. The movement of the link is transmitted to the valve through a radius rod, which is provided with a sliding link block; and by shifting the block from one end of the link to the other, the motion of the engine will be reversed. The return crank is set without angular advance; and, to give the valve the desired lead, a combination lever, driven from the crosshead, and connected to both the radius rod and valve stem, is employed. This lever is so proportioned that, if the radius rod be held stationary, the valve will move a distance equal to twice the lap plus the lead, during each stroke of the crosshead.

As far as the steam distribution is concerned, the Walschaerts gear differs from the Stephenson chiefly in that it gives a constant lead, while with the Stephenson gear the lead increases as the cut off is shortened. The latter arrangement is ordinarily regarded as desirable in a locomotive, but in actual service the two gears seem to give practically the same results, and when properly designed and in good condition, neither gear shows a decided superiority over the other. The introduction of the Walschaerts gear has been due entirely to mechanical reasons, and on those lines where it is now in use, it is generally looked upon with favor.

Both the balanced slide and the piston valve are extensively used on single expansion locomotives carrying high steam pressures. The piston valve is usually made hollow, and arranged for inside admission. The pressure on the two ends of the valve

is thus equalized, and as only low pressure steam is present in the ends of the steam chest, the valve stem stuffing box can readily be kept tight. The Walschaerts gear is advantageously used with this form of valve, as it is then impossible, owing to the constant lead, for the cylinder to be sealed when the piston is at the end of its stroke. This is an important feature, as the piston valve cannot lift from its seat in order to relieve compression. It is also possible, with this form of valve, to locate the centre line of the steam chest outside of the cylinder centre line, and thus place all the members of the valve gear in the same vertical plane, which is desirable. The most recent Consolidation and Atlantic type locomotives on the Pennsylvania Railroad may be cited as interesting examples of the use of piston valves in combination with the Walschaerts valve gear.

Before describing any specific examples of modern locomotives, brief reference should be made to the use of superheated steam. Extensive experiments along this line have been carried out in Germany, and also on the Canadian Pacific Railway, while a few other lines in this country have been trying various forms of superheaters. In the arrangement usually used on the Canadian Pacific, a certain number of boiler tubes are replaced by tubes of considerably larger diameter. These large tubes contain the superheater pipes, through which the steam circulates on its way to the cylinders. This device superheats the steam effectively; although with certain kinds of coal, the tubes are liable to become choked. The fire tube type of superheater has been developed, in this country, by the American Locomotive Company, and has been recently modified by the Canadian Pacific Railway, which has a large number of locomotives equipped with it.

The Baldwin Locomotive Works are at present developing a smoke box superheater. This device consists of upper and lower drums, which are connected by rows of tubes, among which the hot gases circulate while passing through the smoke box. The live steam is passed through successive groups of tubes, thus utilizing as fully as possible, the heat stored in the waste gases. The first superheater of this type was applied to a large freight locomotive built for the Atchison, Topeka and Santa Fe Railroad about two years ago. It has given good results and a number of other locomotives are now being equipped with the device.

The use of superheated steam is attended with unquestioned

economy, and if it is found that superheaters can be maintained without undue expense, their more general use may be expected in the future.

Having now considered some of the features of the modern locomotive, a few specific examples of engines built by the Baldwin Locomotive Works will be illustrated and briefly described.

The accompanying cut represents an Atlantic type locomotive, built in 1904 for the Chicago and Alton Railway. This engine was constructed to designs adopted as standard by the Associated Lines, and was exhibited at the St. Louis Exposition. The cylinders are single expansion, 20 inches in diameter

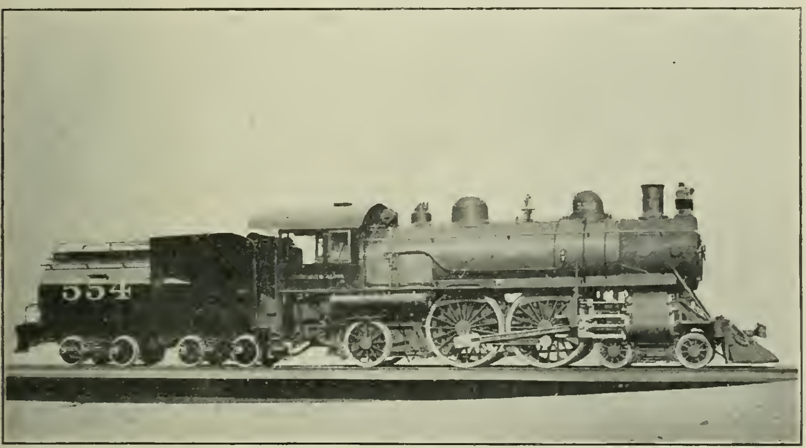


Fig. 1. Atlantic Type Locomotive. Chicago and Alton Railway

by 28 inches stroke. They are fitted with piston valves, which are actuated by Stephenson valve gear. The driving wheels are 81 inches in diameter. The boiler has a wide fire box and carries a steam pressure of 200 pounds per square inch. The tender is of the Vanderbilt type, with cylindrical water tank.

A Pacific type locomotive, similar in many respects to the engine just presented, is shown on the next cut. It was built for the Union Pacific Railroad, and is one of a large number of similar locomotives now in heavy passenger service on the Associated Lines. The cylinders are 22 inches in diameter, as against 20 inches in the Atlantic type engine; while the diameter of the driving wheels is 77 inches. To keep the rigid wheel base within

reasonable limits, the Rushton radial trailing truck is used on this engine, instead of the rigid trailing wheels employed on the Atlantic type. The rear frames are separate from the main frames, the splice being located back of the rear pair of driving

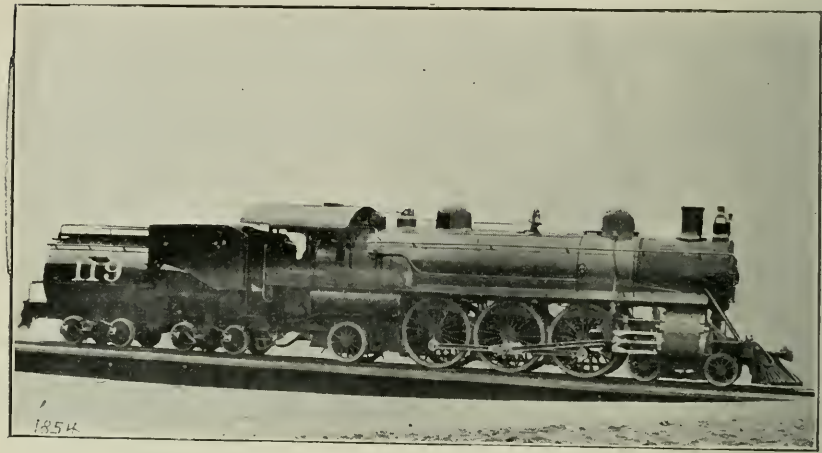


Fig. 2. Pacific Type Locomotive. Union Pacific Railroad

wheels. This is an excellent example of a six-coupled locomotive for heavy passenger service.

The Mogul locomotive shown on the next cut is one of a number used on the Missouri, Kansas and Texas Railway. This

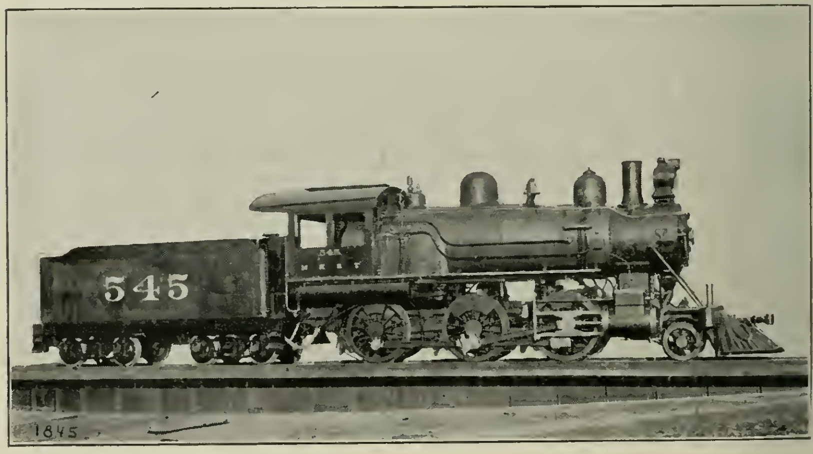


Fig. 3. Mogul Type Locomotive. Missouri, Kansas and Texas Railway

engine represents a type which is admirably adapted to freight service where moderate steaming capacity and tractive power will suffice. The cylinders are 20 inches in diameter by 28 inches stroke. Balanced slide valves, actuated by the Stephenson link motion, are employed. The driving wheels are 63 inches in diameter. The boiler has a wide fire box placed above the rear pair of driving wheels, and carries a steam pressure of 200 pounds per square inch.

The ten wheel locomotive next shown was built in 1905 for the Chicago, Rock Island and Pacific Railway. This type is suitable for heavy passenger or fast freight service. The cylinders are 22 inches in diameter by 26 inches stroke, and the driv-

Fig. 4. Ten Wheel Locomotive. Chicago, Rock Island and Pacific Railway

ing wheels are 63 inches in diameter. The boiler has a wide fire box, and carries a steam pressure of 185 pounds per square inch. The engine is equipped with balanced slide valves, actuated by Walschaerts gear.

A Consolidation locomotive for the same road is shown on the next cut. This type of engine is the most popular for heavy freight service. Nearly 90 per cent. of the total weight is available for adhesion; hence a relatively high tractive power can be secured, and as the weight is distributed over four pairs of wheels, excessive axle loads can be avoided. This locomotive is another illustration of the application of the Walschaerts valve motion. The cylinders are 23 inches in diameter by 30 inches

stroke. With 63 inch driving wheels, and a steam pressure of 185 pounds, the tractive power is 39,600 pounds. Eighty-three locomotives of this class were built by the Baldwin Locomotive Works in 1906 for the Rock Island system.

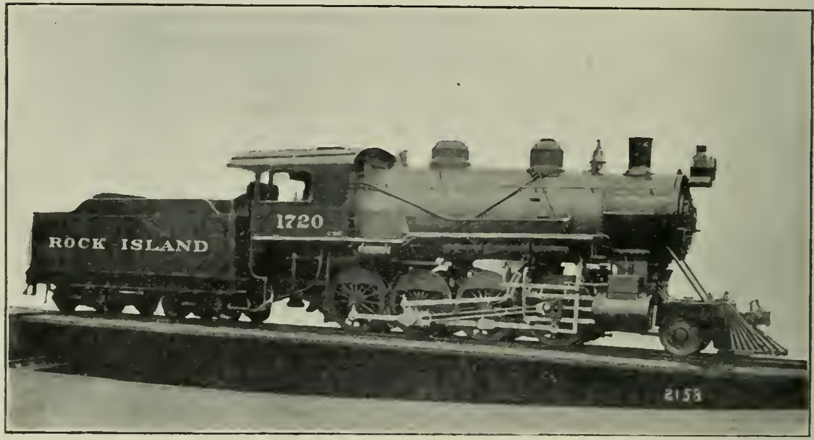


Fig. 5. Consolidated Type Locomotive. Chicago, Rock Island and Pacific Railway

The next cut represents a balanced compound Atlantic type locomotive for the Atchison, Topeka and Santa Fe Railway. Practically all the express traffic on this road between Chicago and La Junta, Colorado, is being worked by engines of this

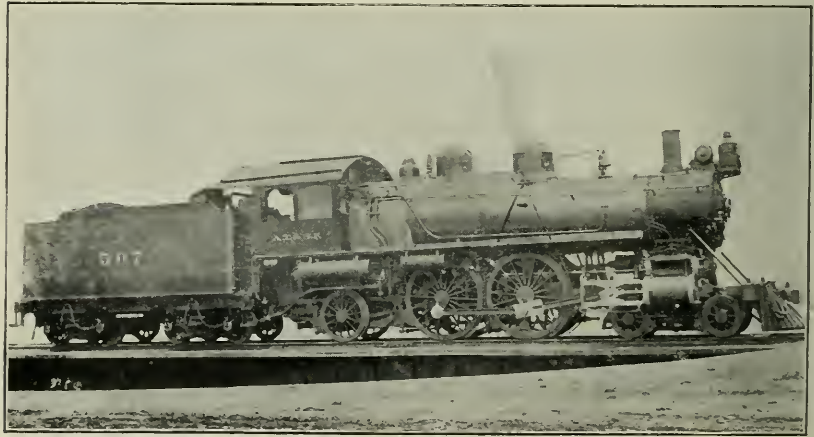


Fig. 6. Balanced Compound Atlantic Type Locomotive. Atchison Topeka and Santa Fe Railway

type, and they are giving excellent satisfaction. Reference has previously been made to the arrangement of the cylinders and running gear in this type of locomotive. In the engine now shown, all the pistons are connected to the leading pair of driving wheels. The cylinder dimensions are 15 and 25 inches diameter for the high and low pressure respectively, the common stroke being 26 inches. The driving wheels are 79 inches in diameter. The boiler carries a steam pressure of 220 pounds per square inch. This locomotive weighs, in working order, 193,700 pounds, of which 101,400 pounds are carried on the driving wheels.

A balanced compound locomotive for the Pennsylvania Lines

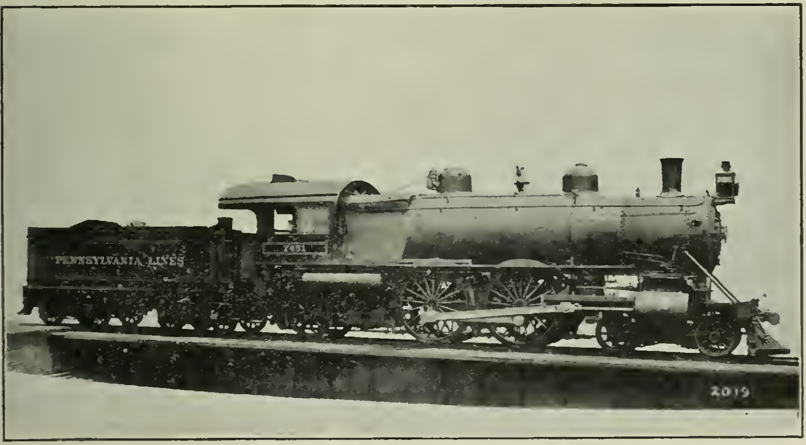


Fig. 7. Balanced Compound Atlantic Type Locomotive.
Pennsylvania Lines West of Pittsburg

west of Pittsburg is next shown. In many of its details this engine follows Pennsylvania Railroad practice. The outside main rods are connected to the second pair of driving wheels—a plan which is frequently adopted, by the Baldwin Locomotive Works, for Atlantic type locomotives having this cylinder arrangement.

The accompanying cut represents one of fifty-seven balanced compound Prairie type locomotives now being delivered to the Atchison, Topeka and Santa Fe Railway. These engines are designed for fast freight service, and are the heaviest six coupled locomotives thus far constructed by the builders. The total weight is 248,200 pounds, of which the driving wheels carry

174,700 pounds. The tractive power, working compound, is 37,830 pounds.

The arrangement of the cylinders and allied parts presents some interesting features. Owing to lack of room it is impossible, in a locomotive of this pattern, to connect the pistons to the leading driving axle. The inside cylinders are therefore inclined at an angle of 7°, and all four pistons are connected to the second pair of driving wheels. The inside main rods pass above the leading driving axle. With this arrangement, the two cranks on the same side of the engine are placed 173° apart, so that the pistons may start their strokes at the same instant. A

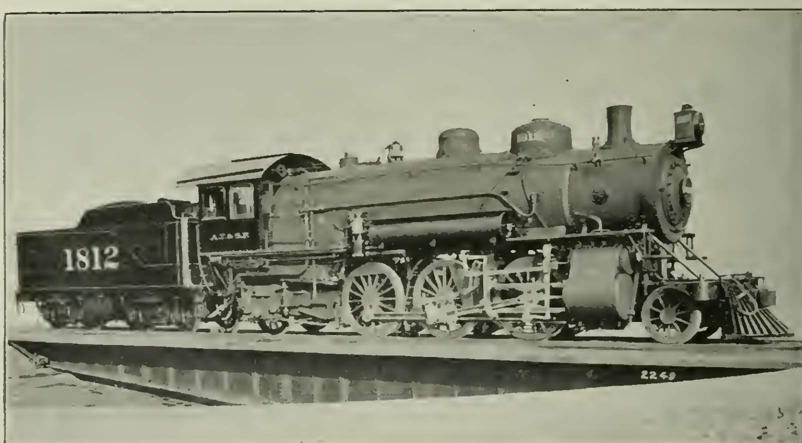


Fig. 8. Balanced Compound Prairie Type Locomotive. Atchison, Topeka and Santa Fe Railway

single piston valve, on each side, controls the steam distribution. The valves are driven by means of the Walschaerts motion.

The boiler is exceptionally large for an engine of this type, and carries a steam pressure of 225 pounds per square inch. The diameter is 76 inches at the front end and 82 inches at the steam dome. The fire box is wide, extending out over the trailing wheels. The total heating surface is 4017.8 square feet and the grate area 53.5 square feet.

The trailer truck is of the Rushton type, with outside journals. The weight carried by the truck is transferred to the boxes through swing links and the truck frame is secured to a radius bar, so that the wheels assume a radial position on a curve. This

reduces the rigid wheel base to the distance between the front and back driving wheels.

Another Santa Fe locomotive, designed for heavy freight service, is shown in the accompanying cut. This is one of over 150 locomotives of the Santa Fe type, which have been built for this road during the past four years. The engine is carried on five pairs of driving wheels and a two-wheeled radial truck at each end. The driving wheels are 57 inches in diameter. The cylinders are tandem compound, 19 and 32 inches in diameter by 32 inches stroke. Each high pressure cylinder is bolted to the front head of the corresponding low pressure cylinder, and both

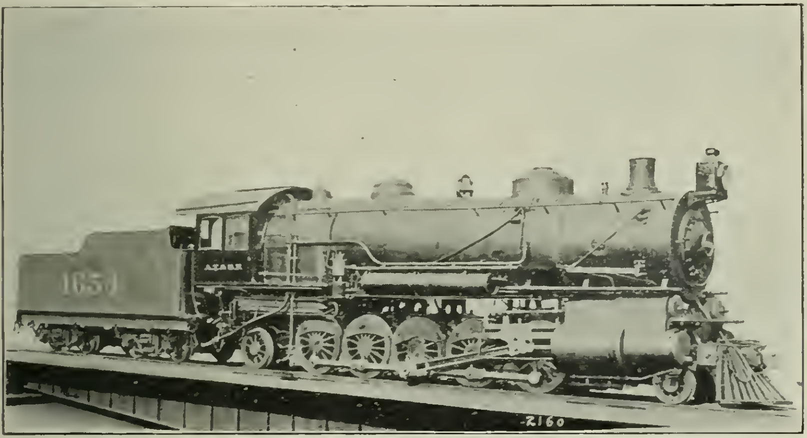


Fig 9. Tandem Compound Santa Fe Type Locomotive.
Atchison, Topeka and Santa Fe Railway

pistons are mounted on the same piston rod. Each cylinder is fitted with a piston valve. The two valves on the same side of the engine are driven by one valve stem, which is actuated by the Stephenson link motion. The weight of this engine is approximately 287,000 pounds, of which the driving wheels carry 234,000 pounds. The tractive power is 62,700 pounds.

The next cut represents one of the largest locomotives thus far completed in the experience of the Baldwin Locomotive Works. This engine is one of five Mallet compounds, built for the Great Northern Ry. Co. in 1906. It is representative of a type which, for some time, has been used in various parts of the world on lines having heavy grades and sharp curves. The re-

cent introduction of the Mallet type into American practice, is the result of a demand for a locomotive having exceptional tractive power and, at the same time, ample flexibility. The driving wheels are divided into two groups. The high pressure cylinders drive the rear group, and the low pressure the forward group. The rear frames are in rigid alignment with the boiler. The front group of wheels practically constitutes a truck, the forward frames being pivoted to the rear frames. The fulcrum is located on the centre line of the engine, between the high pressure cylinders. The latter receive steam from the throttle valve located in the steam dome, through external, rigid pipes. The exhaust

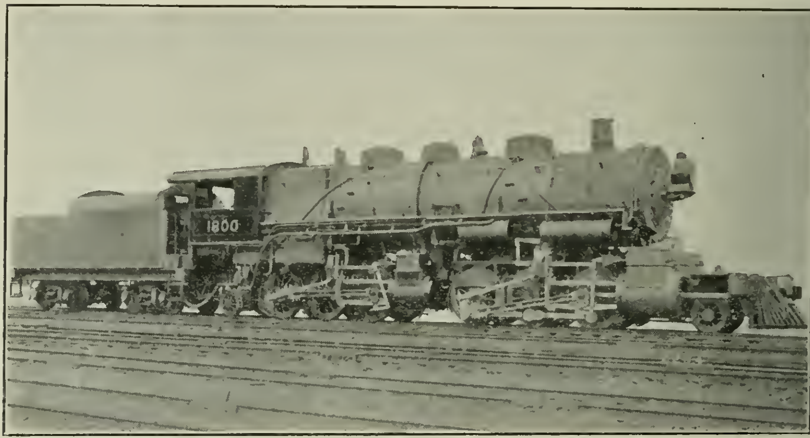


Fig. 10. Mallet Compound Locomotive. Great Northern Railway

steam is conveyed from the high pressure to the low pressure cylinders through a receiver pipe having flexible joints, so that it can accommodate itself to the swing of the forward group of wheels. A flexible exhaust pipe connects the low pressure cylinders with the smoke box. As these pipes carry only low pressure steam, there is practically no difficulty in keeping the joints tight. To give better curving qualities and reduce the flange wear on the driving wheels, the locomotive shown is provided with a two-wheeled radial truck at each end.

The cylinders of this engine are $21\frac{1}{2}$ and 33 inches in diameter by 32 inches stroke. The driving wheels are 55 inches in diameter, and the steam pressure is 200 pounds per square inch. The tractive power is thus 71,700 pounds, and as the weight on

the driving wheels is 316,000 pounds, the ratio of adhesion is 4.4. The drawbar pull of this locomotive is sufficient to lift against gravity, a passenger engine of the type ordinarily used thirty years ago.

The Walschaerts valve gear is applied to each cylinder, and reversing is effected by a McCarroll reversing engine driven by compressed air. Balanced slide valves are used throughout. The boiler measures 84 inches in diameter and contains 5658 square feet of heating surface. The fire box is of the Belpaire type, with 78 square feet of grate area. The weight of the engine alone is 355,000 pounds, and the combined weight of the engine and tender 503,000 pounds.

While it may be questioned whether a locomotive of this capacity is suitable for regular road service, it is of unquestioned value for pusher service on heavy grades. It has practically the power of two ordinary locomotives. The weight is well distributed over a long wheel base, which, however, is sufficiently flexible to enable the engine to round 16° curves. This is a feature of importance in mountain service, where sharp curves are usually frequent.

The types of locomotives which have been illustrated are sufficient to show, in a general way, the trend of modern practice. With the enormous volume of traffic which the railway companies are to-day required to handle, it is almost imperative that each new lot of locomotives be more powerful than its predecessors. Under present conditions a backward step as far as power and capacity are concerned, can scarcely be considered.

But to what is this constant progression tending? and when will the limit be reached? Several Mallet compound locomotives, which will be more powerful than any that have preceded them, will shortly appear. According to the technical press, these engines will have a tractive power of 98,000 pounds, which they will develop in regular road service. The fire grate area will be 100 square feet. The fire box will be as wide as the loading gauge permits, and of maximum length consistent with good firing. It is safe to say that about three tons of coal per hour is the limit which can be handled by a fireman. To burn this amount in the locomotive under notice, the consumption per square foot of grate will be only 60 pounds per hour. This is a low rate for a locomotive, and it could doubtless be considerably increased,

provided a satisfactory method could be found for getting the coal into the fire box.

The tests which were conducted by the Pennsylvania Railroad on the St. Louis testing plant furnish interesting data from which the probable maximum horse-power that can be developed by the steam locomotive may be estimated. These tests indicate that the locomotive is by no means the wasteful machine that it is often thought to be. The two single expansion engines tested showed a minimum steam consumption of about 24 pounds of water per horse-power hour, when cutting off at approximately one-third stroke. Six compound locomotives were tested, and under economical conditions of working, their steam consumption was less than 20 pounds per horse-power hour.

If, now, it is assumed that the average evaporation per pound of coal is 7 pounds of water (which is a high value for much of the fuel used in locomotive work), and that the water rates are as stated above, the fuel consumptions for single expansion and compound locomotives will be respectively 3.43 pounds and 2.86 pounds per horse-power hour. If the maximum amount of fuel that can be handled is 6,000 pounds per hour, the single expansion locomotive can, under these conditions, develop 1750 horse-power, and the compound 2100 horse-power. These very high powers were not reached on the testing plant, but it seems not unlikely that they have been attained on the road under favorable conditions. The speaker, on at least one occasion, has traveled over an approximately level road for a distance of 30 miles at an average speed of 80½ miles per hour. According to the usually accepted formulas for train resistance, the horse-power required for this performance was about 2300, and this was maintained for 22 minutes. The locomotive had single expansion cylinders, and the coal consumption, based on the figures previously given, would be at the rate of nearly 7900 pounds per hour.

There is no way of absolutely verifying the figures just quoted, and they may be too high; but they serve to show that, if the power of the locomotive is to be further increased, the fuel and water consumption per horse-power hour must be materially reduced, or the firing must be mechanically performed. The compound locomotive has shown its ability to develop more power per ton of weight than the single expansion engine, and its in-

creasing use in the future may be expected. The balanced type is the most promising for high speed service, while for slow and heavy freight service the Mallet type seems particularly suitable. Radical changes in design, such as the introduction of the water tube boiler, for example, are by no means beyond the limits of possibility; while superheated steam may play an important part in the solution of the transportation problem.

When the electric locomotive displaces the steam machine in regular road service, it will do so, not because of its increased economy, but because of its ability to perform work which the steam locomotive cannot accomplish. Even at this early period in its development, its ability to accomplish this result has been practically verified.

There is no doubt that the further development of the steam locomotive will be accompanied by the more extensive introduction of refinements in design and construction, tending to improve the efficiency of the machine. This will necessitate better shop and round house equipment, in order that the motive power may be properly maintained, and worked to best possible advantage. The problem of securing adequate transportation facilities in this country is most complex and exceedingly difficult of satisfactory solution; and during the years to come the utmost skill will be exercised, by the railway companies and locomotive builders, in developing the locomotive to the point of maximum efficiency.

PORTLAND CEMENT.

Portland cement, says the Boston *Commercial Bulletin*, has increased in popularity as a building material, not only in progressive countries, but the world over. In far-away India, for instance, it is already in general use, and its advantages are all the time becoming better understood. Wherever wood is used there for structural purposes it is laid in cement if possible, and floors, mouldings, cornices, and trimmings of sand and cement are common, both outside and inside. Houses that have flat roofs are covered with brick dust and particles of brick mixed with cement and packed down hard. Pitched roofs are covered with corrugated iron and then solidly covered with cement and sand. A few figures, perhaps, will best testify to the augmented and still constantly growing uses of cement in India. The imports in that country as long ago as 1870 were valued at $50.342, advancing in the fiscal year 1900 to 729,478 hundredweight, valued at $500.332, and in 1906 to 1,778,428 hundredweight, valued at $1.070.275.—*Eng. and Min. Jour.*

THE CABLE SYSTEM IN TELEPHONE LINE CONSTRUCTION.

The annual report of the American Telephone & Telegraph Company contains the following interesting paragraphs on progress and development in the telephone business:

The improvement in cables within the past few years has revolutionized the art of telephone line construction. Not only is it now possible to place in underground ducts cables containing 400 or even 600 circuits, but a pole line, the carrying capacity of which would have been exhausted by 40 pairs of open wires, can carry 600 pairs of wires in the form of cables. The old-fashioned exchange pole line rarely carried more than 20 pairs of open wires. Sound economy has many times in the past year required the scraping of all the wires on a pole line, cable being substituted for them as the only way of securing the enlargement of facilities required, and not unfrequently has it been necessary to reconstruct the whole line as the cheapest way of securing the opportunity for growth that was required.

If the very great development of the business could have been foreseen, and the engineers and manufacturers had at an early date solved the cable problem so that cables of large capacity could have been originally installed, instead of open wire, in places where a large number of circuits would ultimately be required, much money would have been saved.

Now that it is certain that the business will develop on lines of reasonable profit to an extent much greater than even the most enthusiastic telephone man ventured to expect a few years ago, it would be the height of folly not to anticipate the certain extension of the business by providing facilities for growth when they can be most economically installed.

The great extent to which the telephone business was sure to develop became apparent about the year 1901 when the number of new subscribers increased nearly 220,000, as compared with about 167,000, the largest increase in any prior year. The large increase in the number of subscribers through 1905 which was attended by an equally large increase in toll service, practically exhausted the plant of the Bell Company and involved rebuilding that plant to a large extent. The year 1906 has seen additions to construction which not only enabled the companies to take care of the 2,241,367 subscribers connected with the system on January 1, 1906, and the nearly 500.000 added during the year, but which resulted in plant conditions which will enable future growth to be taken care of with economy. Constant additions will have to be made to the plant, but they will largely be on predetermined lines, utilizing, extending and rounding out the systematic plant conditions that now exist.—*Iron Age.*

The French Government has decided to use the Eiffel Tower as part of the army wireless telegraph system. Using it in the last army maneuvers, the War Department was able to maintain communication with the Eastern frontier along the Vosges, and since then the tower station has communicated with London and Berlin. New installations are being made for maintaining regular communication with Algeria and Tunis.—*Iron Age.*

(Stated Meeting held Wednesday, March 20th, 1907.)

Ozone: Its Nature, Production and Uses.

JAMES HOWARD BRIDGE.

"There is no discovery in modern chemistry that is more important than that of ozone," wrote Frémy, the French scientist, a generation ago; and to this the illustrious Bunsen joined the prediction: "When we shall be able to produce it industrially, hundreds of new applications will arise."

Recent developments in electrical science have been so sensational that the quiet emergence from the laboratory into commercial use of this new agent in industry, sanitation and therapeutics, has been unmarked by any save the few experts who have wrought the change. Our admiration has been challenged by spectacular feats in wireless telegraphy and the like; and the evolution of new manufactures, the application of perfected sanitary processes, the establishment of new therapeutic principles, made possible by the fulfillment of Bunsen's prophecy, have received a few casual notices in technical publications, which have promptly dropped into the oblivion of the files of public libraries.

The Nature and Properties of Ozone.—Ozone is a form of oxygen, which, by readjustment of its molecular structure, has acquired new physical and chemical properties while preserving its original elemental character. A molecule of oxygen consists of two atoms, and in physics the element is written O_2. Ozone has three atoms to the molecule and is written O_3. This extra atom endows ozone with special powers which differentiate it from ordinary oxygen. The differences have been tabulated by the French chemist, Houzeau, as follows:—

Properties of Ozone + 15°.	Properties of Oxygen + 15°.
A gas with strong odor, and a flavor of lobster.	A gas colorless, inodorous, tasteless.

Comences to decompose at about 100° C.

Strong oxidizing agent.

Decolorizes blue litmus.

Rapidly decomposes potassium iodide, liberating the iodine.

Rapidly oxidizes ammonia, and transforms it into nitric acid.

Decomposes hydrochloric acid, liberating chlorine.

Combines with phosphoretted hydrogen with emission of light.

Oxidizes silver.

Corrodes India rubber and cork.

Very stable at all temperatures.

Feeble oxidizing agent.

Without action on blue litmus.

Does not decompose potassium iodide.

Without action on ammonia.

Does not react on hydrochloric acid.

Without action on phosphoretted hydrogen.

Does not oxidize silver.

Does not corrode India rubber nor cork.

Faraday enumerated some of its powers in a lecture delivered as early as 1851 before the Royal Society, as follows:—

"Ozone destroys many hydrogenated gaseous compounds; the combinations of hydrogen and sulphur, selenium, phosphorus, iodine, arsenic and antimony are thus affected. It appears to unite chemically with olefiant gas, in the manner of chlorine.

"It instantly transforms the sulphurous and nitrous acids into sulphuric and nitric acids, and the sulphites and nitrites into sulphates and nitrates. It changes many metallic sulphurets (as those of lead and copper) into sulphates. Like chlorine, bromine and the metallic peroxides, it is a powerful electromotive substance.

"It decomposes many iodides in their solid and dissolved state; by its continued action, iodide of potassium becomes converted into iodate of potassa.

"It changes both crystallised and dissolved prussiate of potassa into red salt, potash being evolved.

"It discharges vegetable colours with a chlorine-like energy.

"It produces oxidizing effects upon most organic compounds, causing a variety of chemical changes; thus guaiacum is turned blue by it.

"From the above enumeration, it would appear that ozone is a ready and powerful oxidizer, and, in a great number of cases, acts like Thénard's peroxide of hydrogen or chlorine and bromine."

The real character of ozone, however, was not known even to Faraday at this date, when the new gas was variously regarded

as hypo-nitric acid, volatilized metallic matter, peroxide of hydrogen, a new element, etc., etc.

Van Marum was the first to notice, in 1783, that by passing electric sparks through a tube containing oxygen, the gas acquired a distinct odor and abnormal oxodizing properties. Cruickshank, in 1801, noticed a similar smell during the electrolysis of water; and Cavallo, soon after, reported that "electrified air" had a purifying effect on animal and vegetable matter, when in a state of decomposition, and employed it as a disinfecting application to foetid ulcers. Cavallo spoke of this condition of the air as the "aura electrica." In 1826 Dr. John Davy (Lectures on Agricultural Chemistry) recognized the existence of this principle in the atmosphere, and published a formula for the preparation of chemical tests to be used in its detection, resembling that afterwards adopted by later investigators. The discovery was then allowed to lie inert until 1840, when the Swiss chemist, Schönbein, observed afresh the peculiar smell proceeding from one of the gases liberated on electrolysis of water. This he recognized as having some similarity to the "aura electrica" developed on the points of an electric machine; and he gave it the name Ozone, from the Greek verb "to smell." The discovery was communicated to the scientific world in a paper to the Munich Academy of Science, and immediately gave rise to numerous controversies concerning the nature and properties of the gas, controversies which lasted many years. Schönbein at first believed it to be a new electro-negative element belonging to the same class as chlorine and bromine. Then he thought it might be one of the constituents of nitrogen; and later he believed it to be a combination of hydrogen and oxygen; and he so wrote to Faraday. In 1845 de la Rive and Marignac asserted that, under the influence of the electric spark, dry oxygen yields ozone; therefore, ozone is nothing but oxygen brought to a peculiar state in which the gas possesses properties which it has not in its natural state. This was combatted by other scientists, including Schönbein himself, who now declared ozone to be peroxide of hydrogen. In 1849 Leuch, representing ozone as galvanized air, O*a*, first made mention of its industrial use "as the most powerful bleaching agent." About the same time Schönbein sent to Faraday a letter written with a manganese sulphate solution, which had turned brown under the action of ozone. He

also announced the re-discovery of Dr. Davy's test to ascertain the presence of ozone by starched iodide of potassium, which is the test applied to-day. Other investigators like Baumert, Becquerel, Faraday, Dr. Hare, of Philadelphia, Frémy, Le Blanc, Andrews and Houzeau took up the subject during the next few years, gradually revealing the properties and constitution of the new gas, until, in 1856, Dr. Andrews, of Edinburgh, confirmed de la Rive and Marignac by showing that "ozone from whatever source derived is one and the same body, having identical properties and the same constitution, and is not a compound body, but oxygen in an altered or allotropic condition."

The Production of Ozone.—The ozone made by early investigators was generally obtained by chemical means. Numerous reactions result in the production of O_3. The most common, and that generally employed prior to the invention of means for controlling the effects of the electric discharge, was the slow oxidation of phosphorus. This is achieved by very simple means. Oxygen diluted three times with air, or ordinary atmospheric air, is drawn by aspiration across the surface of water in which sticks of phosphorus are half immersed. The resulting gas when washed is dilute ozone. At freezing point the production of ozone is nil; but between 15° and 20° C. it is very abundant. The confusing results of early experimenters with ozone were largely due to this method of production; for the ozone was never obtained pure, being more or less mixed with phosphoric acid.

Under the influence of light, and in contact with air, turpentine is oxidized and gives off feeble quantities of ozone, with formation of acids and resinous matters. Other hydrocarbons, coal-tar, various essential oils as those of eucalyptus, lavender, citron, etc., possess analogous properties.

Troost and Hautefeuille report having produced ozone by heating oxygen to 1400° C. to 2200° C. in a porcelain tube; and the statement has been repeated by almost every writer on the subject. It is certain that their observations were defective. It might be inferred *a priori* that, at such temperatures as those stated, any ozone formed would be instantaneously destroyed so as to render its detection impossible. This inference has been confirmed by Mr. J. K. Clement who has made a series of careful experiments in this direction at high temperatures. His results are published in Annalen der Phys., IV, Folge, Vol. 14, 1904.

page 334. He conducted a stream of pure oxygen over the surface of an incandescent Nernst filament, so that it was heated to about 2200° C., while, when streaming away, it was quickly cooled. He could not detect any formation of ozone, nor was any found at the temperature of the arc lamp, about 3000° C. Whenever there were traces of nitrogen present, NO_2 was formed, which, in its reactions, is very similar to ozone; and it seems to be due to this fact that the former investigators thought that ozone had been formed. Clement also gives the results of extended researches on the speed of disintegration of ozone. On the basis of a formula of van't Hoff which can be applied to this case, he finds that at 1,000° C. the content of ozone decreases in 0.0007 second from 1 per cent. to .001 per cent; this means that if ozone is really formed at a temperature of 2200° C. or more, it must disintegrate almost instantaneously when cooled even very quickly.

O. Loew, in New York, in 1870, "blew a strong current of air through a tube into the flame of a Bunsen burner and collected the air in a beaker glass or balloon." "I was thus able," he says, "in a few seconds to collect enough ozone to readily identify it by its intense odor and the common tests." This is another case of inaccurate observation.

Dr. J. K. Boeke, passing oxygen through the luminous flame of a Bunsen burner, found that the peculiar odor and the property of coloring the iodine starch test which were acquired, were due to the production of a compound of oxygen and nitrogen, probably the dinitric trioxide or nitric dioxide.

Oxygen is transformed into ozone under the influence of various radio-active bodies. This suggests a relationship with the chemical rays of the spectrum. If radium is enclosed in a tube filled with oxygen, ozone is formed inside the tube; but if the radio-active substance is sealed in a separate vessel no action takes place on oxygen brought within the influence of the rays proceeding from it. From this fact M. and Mde. Curie came to a notable conclusion, viz., that the transformation of oxygen into ozone required the expenditure of active energy, and that the production of ozone under the direct rays of radium proved that these radiations represented a continuous liberation of energy.

A further deduction may be made: the walls of an ordinary

tube do not permit the passage of ultra-violet rays; therefore there is no action on the surrounding gas. A quartz tube, which is pervious to the ultra-violet rays, would probably yield other results.

Ozone may be produced by numerous chemical reactions, as, for example, that of monohydrated sulphuric acid on bioxide of barium. At a temperature below 75° C. there is produced at the same time hydrogen peroxide.

Kindred results are obtainable with the peroxides of zinc and magnesium on sulphuric acid and with the alkaline peroxides of sodium and potassium. Ozone probably plays some part in the bleaching properties exhibited by these compounds in industrial uses. Permanganate of potash lends itself to similar reactions, but its manipulation requires care to avoid dangerous explosions. The persulphates of potassium, sodium, barium, ammonium, etc., may be decomposed with liberation of O_3, a fact utilized in various industrial applications.

Of all chemical reactions by which ozone is produced, that of fluorine in water is the most promising, an ozone-concentration in oxygen of upwards of 14 per cent. having been obtained in half an hour. If fluorine can ever be made cheaply, its use in the production of ozone may become important by reason of the purity and richness of the gas made possible by its means.

Ozone is also produced by the decomposition of water by the electric current. This, indeed, led to its re-discovery by Schönbein. The process is aided by adding acid to the electrolyte. The electrolysis of acidulated solutions of potassium permanganate yields more ozone than does the electrolysis of acidulated water; but neither process has any commercial interest or value in comparison with the perfected electrical methods in use, now to be described. The highest yield of ozone reported of electrolytic processes is 3 grams per K. W. hour of energy expended.

The neutralization of two opposite charges of electricity known as an electric discharge, produces a variety of effects when it takes place through a separating body of oxygen or atmospheric air. These effects are luminous, heating, chemical, mechanical and magnetic. Most of them do not concern us here. In ozone production it is the chemical action which is sought; and the luminous, heating and other effects are accidental and often undesirable accompaniments.

A discharge may take place in any of several forms, chiefly, the arc, the spark and the glow. The arc-discharge is accompanied by the production of light, intense heat and energetic chemical action, especially on the nitrogen of the air, which, in the presence of moisture, it converts into nitrous and nitric oxides. The spark, or disruptive discharge, has similar chemical and heating properties, but gives out less light. The glow or silent discharge has little light, less heat and, in air, acts almost exclusively on its oxygen. Only when moisture is present

Fig. 1. Showing a small arc-discharge.

does it act upon nitrogen, and then only in a very small degree as compared with the other forms of discharge.

Figure 1 is a reproduction of a small arc from an alternating current transformer. It may assume a length of several feet, is characterized by a humming sound, a flame-like shape ever changing, and, as already stated, produces an intense heat. It is a continuous discharge of great current strength, and hence of great danger to the life of the apparatus.

Figure 2 is a spark discharge. It is a yellow-white, zigzag, loud snapping, oscillatory discharge. Figure 3 is a photograph

taken of 10 consecutive sparks from a static machine, as shown in Figure 2.

Figure 4 is a spark from a Rumpkorff induction coil operated by a high frequency interrupter. It is a mixture of the spark and violet brush discharge previously spoken of as the glow.

Figure 5 is the glow or silent discharge. It is characterized by a dark blue violet color. It is a convective discharge, unidirectional from positive to negative.

Figure 6 is the same kind of a discharge proceeding from the negative pole of a static machine. It may be noted that this form of discharge, whether proceeding from the positive or the negative pole, assumes an essentially cone-like shape with a hollow interior. Recognition of this fact has recently wrought important changes in the art of ozone production. This violet-colored discharge is the only one by which ozone may be continuously produced with any practical degree of purity.

The theory has recently been advanced, and is now gaining pretty general acceptance, that the formation of ozone by the brush or silent discharge is caused, not by any direct electrical action on the oxygen itself, but is simply a photo-chemical effect, due to the ultra-violet rays accompanying such discharges.

This theory, which seems destined to revolutionize our conceptions of ozone-formation, originated with the discovery of Lenard, who noticed that if the light from a spark gap was allowed to pass through quartz plate, which is transparent to ultra-violet rays, and to impinge on oxygen, ozone was generated. If, however, a substance impervious to ultra-violet light was interposed, no such action took place. Goldstein followed up the discovery by showing that the ozone odor existed on the outside of Geissler tubes through which a discharge was passing, only, however, if the tubes were partly of quartz. Warburg then announced that ultra-violet light and cathode rays accompanied the discharge in a Siemans tube; and with the assistance of Regener he showed by volumetric tests that, in addition to the ozonizing action of the rays, a deozonizing action was at work, and that the relative rapidity of the two processes was fixed. Fischer and Braehmer advanced the discovery a step, when experimenting with a quartz mercury-vapor lamp rich in ultra-violet rays, they found the chief factors determining the process to be the temperature of the gas, the light intensity of the lamp, the rapidity

of the stream of oxygen and its purity. In their experiments the temperature of the lamp, without cooling, went to 270° C., at which of course ozone does not exist; but by lowering the tem-

Fig. 2. A spark-discharge.

perature, the yield of ozone underwent a gradual increase. By maintaining the low temperature and increasing the intensity of the light, higher yields of ozone resulted. As the concentration increased, the yield diminished. Thus:

Per Cent. O_3.	Milligrams O_3.
0.192	0.571
0.201	0.593
0.234	0.540
0.230	0.528
0.249	0.382
0.259	0.382

By doubling the current the ozone generated was also nearly doubled.

This interesting theory has received collateral support from the investigations of Franz Richarz and Rudolph Schenck, who have pointed out the analogy between radio-activity and the behavior of ozone. They have shown that freshly prepared ozone, or ozone that is being decomposed under the influence of de-ozonizing agents, accelerates the condensation of water vapor. The presence of gaseous ions to which this phenomenon points, is further indicated by the considerable conductivity exhibited by ozone. In respect to this ability to produce gaseous ions, ozone is similar to radium and other radio-active substances. Further, a current of ozonized oxygen is said to cause a zinc sulphide screen to floresce, although barium platinocyanide and zinc oxide are unaffected. Red phosphorus, inert in oxygen, shows luminesence in ozone. Another point of analogy is the fact that radium salts and ozone both decompose with considerable development of heat.

In its simplest form an ozonizer consists of two metallic bodies separated from each other by a short gap, across which a current of electricity may be passed, in the form of a blue-flaming discharge, from one metallic body or electrode to the other. The electrification of the air in the path of the discharge produces the molecular changes involved in the conversion of O_2 into O_3.

This so-called silent or ozone-making discharge may be produced in several different ways. The earliest mechanism employed for this purpose was a static machine. This also gave off sparks, which, as stated above, in moist air, resulted in the formation of nitrous products which, mixed with the ozone, led to confusion in the minds of early investigators as to the real nature of the gas. A current from a battery of cells may be passed through an induction coil furnished with an interrupter;

and this will give a small but steady and efficient ozone-making discharge. The direct current from a dynamo may also be used if passed through a similar coil. It is, however, the alternating current from a dynamo of high periodicity, stepped up to several

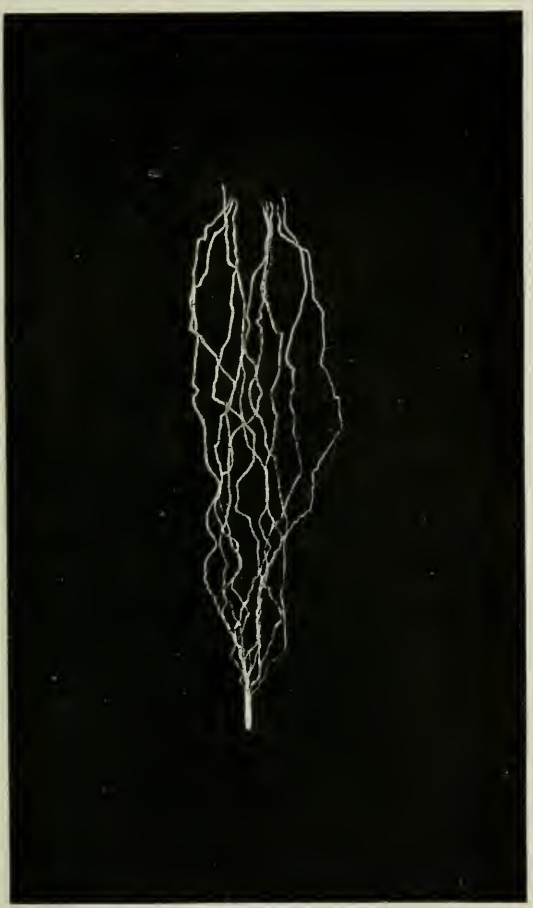


Fig. 3. Sparks from a Static Machine.

thousand volts, which offers the best means of obtaining the silent discharge; and this is the means in general commercial use to-day. Such an apparatus, however, may give any one of the three kinds of discharge described. The arc discharge by its intense heat destroys the apparatus, while the spark discharge

transforms the nitrogen of the air, mixes it with the transformed oxygen and gives impure ozone. Means must, therefore, be taken to prevent these undesirable forms of discharge, and to limit the apparatus to the production of the silent effluvium which transforms the oxygen of the air into its allotropic condition. To attain these ends the inventive faculties of all the investigators in this field have been directed for many years.

It was early discovered in the art that when a non-conducting substance like glass, mica or vulcanite, was placed between the poles of an electric machine, across the path of the current, the formation of sparks and arcs was prevented, and the current assumed the form of a silent blue discharge, which produced large quantities of ozone, varying in strength and amount with the tension and flow of the electric current. As this tension, or mechanical stress, requisite to overcome the resistance of the air as well as of the dielectric was necessarily very great, it frequently happened that the interposing glass or mica body was fractured under the strain, and before the current could be turned off an arc was formed which destroyed the mechanism. Efforts were therefore made to eliminate the dielectric; and many years of experiment and large sums of money have been expended in devising means to this end.

As regards the various yields of existing types of ozonizers, the differences in methods of testing render comparisons unreliable; and, until a uniform method is applied to determine the ozone-content of a given body of gas, no exact comparison can be made between the efficiency of the different types of apparatus now in use.

The Siemens & Halske ozonizer, with dielectrics, is reported to yield 20 to 30 grams per K.W. hour. Elworthy claims 60 to 70 grams from a machine of similar construction; but no data are available as to the richness in ozone of this product. Otto has published figures showing yields of 20 to 118 grams per K.W. hour, the former where the concentration was .852 grams per cubic meter of air, and the latter where it was only .542. Vosmaer with a concentration of 1.5 obtained a yield of 12 to 16 grams. The de Fries apparatus produces about 20 grams with a concentration of 1.0. Generally speaking, 20 grams has hitherto been considered a fair output if the air treated contains one gram and upwards of ozone per cubic meter.

A very noteworthy increase in the efficiency of ozonizers has recently resulted from a simple observation made by the author. Reference to the photographs of the silent discharges printed on pages 369 and 371 shows that these are cone-shaped funnels. They may be conceived as hollow cones of light. In all ozonizers

Fig. 4. Spark from an Induction Coil.

hitherto devised, the air is directed against, or around, these cones of light in a plane at right angles to them. Now it is a well known fact that when electricity is discharged from a point, the surrounding particles of air are electrified, and, being of the

same electrical sign, repulsion takes place. The currents of air repelled from the points of a discharging electric machine may be felt by the hand, or seen in the deflected flame of a candle held close to them. The well known electrical toy, called Hamilton's Mill, rotates because of this repulsion of the electrified air from the discharging points. With these facts in mind, it is obvious that air, when passed into the influence of a discharge at right angles to its path, is immediately thrust away from it, and any effect which the discharge may have on it is but momentary. This is an obvious disadvantage where it is sought to bring about that molecular readjustment in the particles of air submitted to electrification which accompanies their conversion into ozone.

To overcome these disadvantages the writer has devised a perforated electrode, and so arranged the air supply that it passes through the perforations in fine streams directly into the hollow cores of the discharges taking place on its surface. In this way the air is forced to travel first upwards with the discharge, while completely surrounded by it, and then forced through the luminous walls of the discharge. This brings every particle of the air into intimate contact with the discharge. The first tests of the apparatus gave 80 grams of ozone of a high concentration. The principle, thus proved so revolutionary, has been recognized as novel in the art by the patent offices of America and Europe.

An extension of this principle, which logically follows, is that by which the treated air is instantly led away from the deozonizing effects of the heat of contiguous discharges by withdrawal through the perforations of an opposing electrode. In this way air first passes directly into the core of a discharge taking place from one electrode, which, for convenience, may be called the anode, and is thence led directly into the core of a second discharge taking place from the opposing electrode or cathode, and so passes at once out of the influence of the discharges through the cathodic perforations. Of course, this can only be done when no dielectric is placed between the dischargers; and arcing and sparking must then be prevented by employing the usual resistance in the circuit between the source of energy and the discharge.

Ozone in Water Purification.—Considerable difference of opinion exists among experimenters concerning the minimum

concentration of ozone requisite for the effective sterilization of water. Tests have been made in Europe with concentrations as low as 0.5 gram per cubic meter of air and as high as 15 grams. In each case satisfactory results have been achieved, as shown by bacteriological tests. Indeed, as low as 0.3 was found effective by Professor Van Ermengem in tests made at Brussels. At Gennekin, Schneller has successfully used concentrations as low as .537. At Rotterdam, Van Delder, using the Vosmaer system, obtained satisfactory results with an average concentration of .8;

Fig. 5. Silent-discharge from positive pole of a Static Machine.

and Professor Proskauer, at Berlin, found .9 to 1.8 efficient. The following is an extract from the report of tests of the de Fries plant near Paris made by the official authorities of that city:—

Concentration.	Air per M_3 of water in cubic-meters.	Total ozone per cubic meter of water.	Bacteria Before ozonization.	After ozonization.	In the collecting tank.
1.6	1.383	2.216	800	2	4
1.04		2.035	850	3-4	
.98	2.077	1.352	2682	3	

.88	1.537	2.04	3732	7	
1.	1.003	1.	2886	9	
.835	1.003	0.693	2886	45	
1.12	1.037	1.61	4445	14	9
1.43	0.831	1.188	145	2	1

At Weisbaden and Paderborn, Germany, the Siemens & Halske apparatus in use there show the following results:—

Concentration in grams of ozone per cubic meter of air.	Number of germs per c.c. Raw Water.	Ozonized Water.
1.4	39,000	8
1.7	26,000	12
1.6	55,000	5

At Philadelphia, during a protracted series of tests during the year 1905, the following results were achieved with low concentrations:—

Concentration.	Oxygen consumed. Before.	After.	Air in cubic feet.	Water treated. Gallons.	Bacteria. Before Ozonization.	After Ozonization.
.7	1.34	.37	4950	12800	12500	19
.64	.74	.57	5020	37500	4600	200
.68	1.01	.97	4800	37000	600	60
.35	1.06	.83	4840	35400	160	11
.49	1.77	1.03	5010	20200	75	10
.6			4930	20000	5400	15
.78			3045	29700	170000	42
.83			3080	30500	130000	70
.87			4196	28200	80000	34
.47			4196	31800	1200	20
.62			3113	30650	73000	250
.91			2775	29100	1800	9

The quantity of ozone absorbed varies with the amount of organic matter contained in the water. In distilled water ozone is but slightly soluble. Nor does the number of bacilli present in water make any preceptible difference in the amount of ozone absorbed; for however great their number may be, they represent an infinitesimal weight of organized matter to be consumed. Otto finds the ozone absorption of waters treated by him to vary between 0.5 gram and 0.8 per cubic meter of water treated, and asserts that these figures are corroborated by tests made by Dr. Erlwein at Weisbaden. Similarly, at St. Maur, Mr. Van der Made, engineer to the Sanudor Co., told the writer he had found

that about half a gram of ozone is absorbed in the sterilization of a cubic meter of river Marne water after rough filtration.

The unutilized ozone is withdrawn from the surface of the sterilized water by Otto, de Fries and Siemens & Halske, and passed in continuous, successive cycles through the ozonizer and sterilizer. In this way they claim to save about two-thirds of the ozone produced. In the Howard-Bridge method the unabsorbed ozone is drawn from the treated water by the suction action of another current of water running rapidly down a U-shaped tube, sunk deeply into the ground. Here it is all used up in the preliminary oxidation of organic matter, so that when fresh ozone is added to this water the ozone is free to act with its primal

Fig. 6. Spark-discharge from negative pole of a Static Machine.

strength upon the bacteria. In the Vosmaer system the excess of ozone is allowed to escape into the air.

A number of mechanical means have been devised for mixing the sterilizing gas with the water under treatment. The one most generally used consists of a tower, sometimes filled with stones or other inert matters over which the water trickles and meets the ozonizing gas forced into the tower at the bottom. This is the column invented by Gay-Lussac and called by his name. It was used by de Meritens, the pioneer in ozone sterilization, and adopted by Siemens & Halske in their installations at

Weisbaden and Martinikenfelde near Berlin. It is a simple and efficient means of mixing the sterilizing gas and water. Analyses by Dr. Erlwein of the water before and after purification, covering a period of several days, yield the following reports:—

Bacteria per c.c. before Purification.			Bacteria per c.c after Purification.		
Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.
200,000	2,300	80,000	34	0	8

All pathogenic germs were destroyed. The amount of ozone used per cubic meter of water treated was 1.3 grams.

According to Dr. Erlwein, the cost of this process per cubic meter of water (264.17 American gallons) for a plant treating about 250 cubic meters per hour is 2 pfennigs or half a cent.

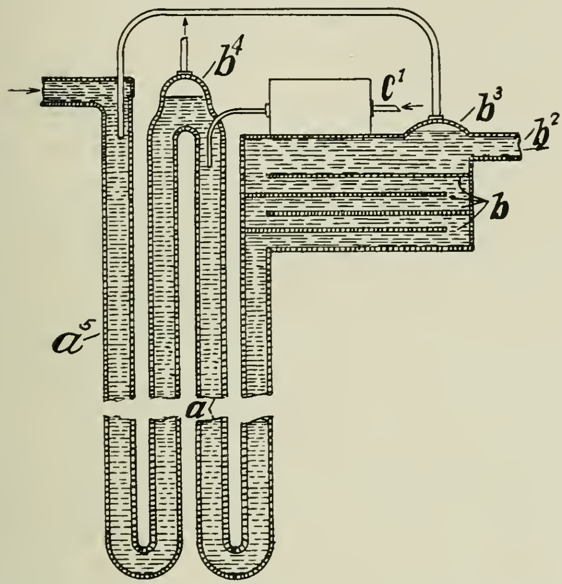
In American equivalents this is at the rate of $18.92 per million gallons in a plant capable of treating about 60,000 gallons of water an hour. Dr. Erlwein estimates that for a similar plant of 10,000,000 gallons a day capacity, the cost of operation would be about $7.00 per million gallons.

In the de Fries system the water and ozonized air are mixed in vertical cast iron cylinders enamelled inside. The water and air are introduced at the bottom and leave the apparatus at the top. The cylinders are divided into compartments by horizontal celluloid trays perforated with numerous small holes. On passing through these perforations the water and air are brought into close contact.

The operation of these and other systems involves the use of an air compressor for forcing the ozonized air into the column of water. As seen in Dr. Jackson's report on the Vosmaer tests, this required 4.4 H.P. hours for the treatment of 25,650 gallons. This is at the rate of about 160 H.P. hours or 110 K.W. hours per million gallons treated. In addition to this expenditure of energy, there are other disadvantages inseparable from this method of mixing the air and water. Ozone has such active oxidizing properties that ordinary lubricants cannot be used in the cylinder of an air compressor. The rings of the piston must, therefore, fit so tightly that if air is passed through the cylinder containing the least moisture, the machine either works with great difficulty and loss of power, owing to the swelling of the piston rings, or else stops entirely.

This difficulty is overcome, and a large part of the cost of

operating an air compressor is saved, by the Howard-Bridge process of causing the suction action of the water under treatment to draw into itself the ozonized air required for its purification. This principle is roughly shown in the accompanying drawing, which also illustrates the further advantage already mentioned, in that the excess of ozone which remains unabsorbed, and which in some systems is run to waste, is here utilized in the prelimin-



Raw water enters the pipe a^5 drawing, by suction, unabsorbed ozone from b^3. The waste gases escape at b^4. The current of water in a sucks fresh ozone into itself from the ozonizer c; and after passing around the baffle plates in b, the purified water escapes at b^2.

ary treatment of the water. By this system municipal water supplies can be sterilized at one-half the cost of slow sand-filtration, which never wholly removes bacteria.

The Industrial Uses of Ozone.—The difficulty of obtaining ozone continuously and economically, and of practical strength, has prevented its general adoption in those industrial arts to which it was found by early investigators to be theoretically applicable. Now that this has been overcome, and the gas can be produced in large quantities at slight cost, its application to

numerous manufacturing processes will probably no longer be delayed.

There are some compounds in nature and in intermediate stages of manufacturing that are comparatively worthless, which, if a single atom of oxygen were added to their molecules, would be transformed into products of greater value. Here is a theoretical illustration: Succinic acid is formed of four molecules of carbon, six of hydrogen, and four of oxygen. Add a molecule of oxygen, and malic acid results. Add still another and tartaric acid is produced. Thus:—

$$\begin{aligned}\text{Succinic Acid} &= C_4H_6O_4\\ \text{Malic Acid} &= C_4H_6O_5\\ \text{Tartaric Acid} &= C_4H_6O_6\end{aligned}$$

Ozone readily yields this additional molecule of oxygen to other elements or compounds, and this faculty may be utilized to add to their commercial value. Oil of cloves, for instance, has little value in comparison with the extract of vanilla bean; yet by ozonization it is converted into substance which for all practical purposes has taken the place of the natural extract, once so costly that it was stored in steel vaults. The writer was told by one of the inventors of this process that the entire cost of vanillin is only half the amount of the duty with which the Government of the United States has protected this infant industry. Vanillin, thus produced, is used for flavoring confectionery and ice cream from California to Maine.

Professor C. Harries, who has done excellent work in this new field of research, shows that "experimental results in ozonization lead to the conclusion that all organic compounds containing an ethylene linkage (double bond) add one molecule of ozone, giving rise to a new class of substances termed ozonides." "This method of work," he adds, "has already proved its value in permitting the comparatively easy preparation, in fairly large quantities, of many substances which were hitherto unknown, or could only be obtained with the greatest difficulty."

Sulphuric acid, which is the basis of many chemical industries, is made by simply ozonizing water containing sulphur. Whether this method can compete with existing processes, in which sulphuric acid is often a by-product, can only be determined by trial on a commercial scale.

One of the least expected applications of ozone is in the extracting of gold from its ores. This forms the subject of a serious paper by de la Coux in *Génie Civil,* February 14th, 1903, who says: "In treating auriferous minerals by solutions of hydrochloric acid submitted to the action of ozone, we have been able to obtain a rapid dissolution of the gold. There may be here," he adds, "a process capable of application in the treatment of auriferous minerals."

Peroxide of nitrogen is being made every day in flour mills in England by electric discharges. This is effected by subjecting ozonized air to a sparking discharge, which modifies the nitrogen of the air, and causes it to combine chemically with O_3 formed during the first part of the process.

The action of ozone on chromium is to convert it into chromic acid, which is extensively used in various industries, especially in tanning. The preparations of chromium sold to tanners bring a high price; and it is not unlikely that their manufacture can be cheapened by the new oxidizing agent.

Permanganic acid is formed from the prolonged ozonization of certain salts of manganese, which, contrary to the usual reaction, here lose a part of their oxygen. This may have no commercial value as yet; but the reactions of ozone on manganese are so numerous and interesting as to have excited some chemists to enthusiastic search for new combinations of the metal which may be found profitable. Oxides of zinc and lead are easily produced by means of ozone, but, perhaps, not so cheaply as by the electrolytic process accidentally discovered by the writer and brought to commercial completeness by Mr. Carlton Ellis. Metals, with the exception of aluminum, platinum, gold and perhaps one or two others of the very rarest of them, are readily oxidized by ozone, especially in presence of water. Here is a large field, as yet unexplored by the seeker for new industrial products.

In organic chemistry a wide vista of new industrial effects is opened through the agency of the new gas. Otto, to whom we owe so much of our knowledge of ozone and its properties, has produced formic acid and formic aldehyde from methane or marsh gas. Here we have the basis of a new tanning agent and a powerful disinfectant created, as it were, from nothing. By ozone iodoform has also been made by Otto from iodide of

potassium and alcohol, and the process is commercially practicable.

The bleaching and refining of mineral oils was one of the first industrial uses to which ozone was applied; but the cost of the gas prevented its development. This may now be changed. Otto has prepared from petroleum an ozonized jelly having strong antiseptic, parasiticidal and disinfectant properties, which he calls Petrole-Ozoné.

According to various experimenters, Mare, Ney and others quoted by de la Coux, camphor has been made by ozonizing turpentine; and the process gives promise of having commercial value.

Numerous methods have been devised, and patents taken out, for the bleaching and purifying of sugar and syrups by ozone; but these have hitherto failed owing to the difficulty of producing the gas. In these processes ozonization is generally assisted by electrolysis; and some striking results of the double action thus obtained are published by de la Coux. These are too long to reproduce here, but they may be summarized as follows:—

	Decoloration and increase in purity, Per cent.		
	By ozone.	By electrolysis.	By ozone and electrolysis.
Decoloration	35	75	95
Purity	8.5	21	36
Saline coefficient	10	27	137
Organic coefficient	14	31	47

The Philadelphia ozonizing plant has been investigated by the experts of one of the principal refining companies in the United States, but the results of their tests have not been made known.

The bleaching properties of ozone have been applied industrially to the whitening of wax, gum lacquer, ivory, bone, feathers and various other things, with more or less success. In the manufacture of linoleum it has been found of special advantage in that the oils successively applied to the cloth are quickly oxidized, so that the capacity of the factory is increased, while the incidental bleaching of the oils results in a brighter and cleaner-looking product. Similar results have followed its use in oxidizing the varnish on "patent leather," glazed kid and the like.

In the manufacture of starch ozone has been utilized as a

bleaching agent, and has led to an incidental product intermediate between starch and dextrine which, it is stated, is taking the place of gum arabic in the textile industries. Two large plants are said to be in successful operation in Germany, one at Kryitz and the other at Fuerstenwalde. This illustrates the unseen possibilities offered to investigators by the new oxidizing gas. So far as the writer knows, ozone has not been used in the manufacture of glucose. It is possible that its use would so modify the residues of the sulphuric acid employed in its manufacture, as to rid it of its injurious properties when used as a food.

In this connection Dr. Fröhlich, of Messrs. Siemens & Halske, in illustrating the bleaching properties of ozone, states that 20 grams of ozone per H.P. hour "will bleach 110 pounds of linen as well as grass bleaching during three days; it will in presence of chlorine, bleach and refine 88 pounds of potato starch to such a degree that the color becomes a clear white and the bad odor and taste are removed; if this is roasted and ozonization is continued a product resembling gum arabic is obtained; 20 grams of ozone being sufficient for 66 pounds of this product."

For the use of the tanner an excellent substitute for degras, an expensive softener of which the supply is constantly dwindling in proportion to the demand, has been produced by ozone from inexpensive oils. Here is a chance for the creation of a new and profitable industry.

Roscoe is said to have produced aniline from alcohol years ago; and the researches of Otto have shown, close to this field, a wide range of unexplored territory awaiting commercial development. In the synthetic production of indigo ozone may have an important role; as it has been found to possess in the preparation of artificial perfumes.

In a single month in 1903, the Société Francaise de l'Industrie Chimique produced 22,000 kilograms of vanillin by means of ozone, which at 35 to 45 francs has taken the place of a product that in 1895 was worth 800 francs. The German firms previously making vanillin synthetically are said, by de la Coux, to have closed their factories, and now buy their supplies in France. The method employed in France and at Niagara Falls is patented, and has yielded its owners enormous profits.

Other unexpected uses for ozone have been found in the hardening and ripening of wood for special purposes, such as musical

instruments, and, in striking contrast, in the stimulation of silk worms. In Paris, the linen from hospitals is disinfected by ozone and a large laundry in the St. Honoré market has long used the gas in this way. Other uses that have been suggested for it is the purification of illumination gas, the improving of cigars and tobacco—of which it is stated "the aroma and finesse are increased," the removal of undesirable odors from raw coffee, and the destruction of the phylloxera. These more or less doubtful suggestions may be omitted, and the actual applications already enumerated, will sufficiently indicate the wide and diversified range of the industrial uses to which this powerful oxidizing agent may possibly be applied.

Ozone in Therapeutics.—In 1887 Dr. Donatien Labbé, using a Houzeau vacuum tube, produced pure ozone by the silent discharge. This he found he could inhale in doses which had previously been considered injurious; and he thereupon commenced a series of experiments on tuberculous and anemic patients which for the first time fully established the high therapeutic value of the gas. In 1889 Dr. Huguet de Vars installed several ozonic sanitariums in Paris and in the south of France, where he is said to have cured his patients by means of ozone in inhaling rooms. In 1891 Dr. Labbé presented the results of his several years' experiments in the ozone treatment of tuberculosis, etc., in a paper read before the French Academy of Sciences. The curative effects set forth in this paper produced a profound impression on the medical world. Ozonizing apparatus were installed in several French hospitals; and in May, 1892, at the Lariboisière the wounds of the victims of the dynamite explosion at Véry's restaurant were bathed with ozonized water.

Upon the nutritive functions ozone inhalations have a stimulating effect. Perisalsis is markedly quickened, so much so that the characteristic griping sensations following the use of an energetic cathartic are sometimes experienced after a short inhalation. There is increased elimination of urea and phosphoric acid, which indicates a corresponding stimulation of the kidneys. Improved appetite accompanies and succeeds a prolonged series of ozone inhalations, and the fact, reported by nearly all investigators, that the iron constituents of the blood are increased, shows improved nutrition. Since the iron is not conveyed into the blood by the inhalations, it must necessarily be derived from

the food; and this indicates a more efficient working of the entire nutritive system.

The physiological changes thus indicated show that ozone may be advantageously used to correct the conditions producing anemia; while the increased elimination of urea and phosphoric acid found by Dr. Peyrou and confirmed by Drs. Labbé, Oudin and Caritzalis, may be considered as indicating possible beneficial effects of ozone in gout, rheumatism, diabetes, etc.

On the circulatory system ozone again acts as a stimulant, and patients generally show the effect of this by heightened facial color. A slight dizziness sometimes follows its inhalation, indicating increased capillary pressure. The writer has found that headaches due to night-work are relieved after inhaling the gas for fifteen or twenty minutes. This stimulation joined to the increased richness of the blood in oxyhemaglobine—that is, in its oxygen carrying properties—may account for the many cures reported of troubles due to defective circulation and suboxidation.

On the blood current itself the oxidizing properties of ozone have been observed as distinctly as in the case of other liquids. Specific blood poisons are reported to be eliminated with remarkable rapidity. Scrofulous and even syphilitic toxines are said to be especially amenable to this form of treatment, when they have been found to yield to no sort of drug medication. If this is so, there is no reason why other toxines like that of tetanus, ptomaine poisons, malaria and the virus of rabies, may not be oxidized into innocuous forms, and eliminated from the blood by the usual channels. It is said by de la Coux that ozone "is indicated in the treatment of cancer and other infectious maladies; and many physicians are actively employing ozone in the treatment of these diseases in the medical institutes of France." If this is so, it is unfortunate that reports of their treatment of cancer should not have been published to the world.

The increased action of the heart and the perisaltic movement of the bowels, just spoken of, indicate that ozone inhalations have a direct influence on the nervous system. This is said to be especially marked when neurasthenic patients are submitted to a course of treatment.

The bactericidal action of ozone is so pronounced that it is not surprising to find it especially effective in diseases of microbic

origin. In tuberculosis, catarrh, influenza, grippe, bronchitis, whooping cough, croup and other affections of the respiratory organs due to microbic invasion, the bactericidal properties of ozone are said to act with almost miraculous promptness. And not only does the gas act as a direct microbicide, but it has an indirect bactericidal action as a result of the modifications it is said to produce in the tissues forming the media on which the bacteria lodge and propagate—modifications which render these media unfavorable to the development of the bacteria. This, if true, is a physiological modification of the highest importance in therapeutics; and the claim seems to be based on a reasonable explanation. It is this: ozone modifies the constitution of the blood and of the intra-cavital fluids by rendering them more acid than before; and Dr. Oudin claims that it does this in strong proportions. Now it is well known to biologists that bacteria will only grow in alkaline media. The least acidity kills them. Even a neutral culture of bouillon inhibits the growth of these organisms. Thus ozone not only destroys the bacteria infecting the tissues with which it comes in contact, but it produces in the tissues themselves a physiological condition hostile to other germs which may afterwards find lodgment on them.

Another factor may possibly here come into play. Modern research tends to prove that infectious diseases are not caused directly by the action of bacteria themselves upon the tissues, but by the production of soluble poisons of the nature of alkaloids. This theory has so far advanced beyond the realm of conjecture as to be generally accepted as a final explanation of the symptoms of infectious disease. By ozonization the alkalinity of these toxins is probably neutralized, and so they are rendered inert That this takes place in laboratory tests has been abundantly demonstrated; and the results reported by physicians of actual experiences seem to indicate that kindred effects take place physiologically. If this should prove to be the case, the therapeutic value of ozone will have a scientific basis of fact that will compel its recognition by pathologists everywhere, and ensure its general adoption in the treatment of all diseases due to the invasion and activity of bacteria.

When we recall the fact that over forty per cent. of deaths are caused by diseases having a microbic origin, and therefore due to infected air, food or water, to which the sterilizing action of

ozone may serve as a preventive; when we recall another long list of diseases having their cause in malnutrition, imperfect circulation and defective nervous conditions, capable of amelioration in ways indicated above, it would seem that ozone presents itself as the most efficient, most readily accessible and easily administered therapeutic agent ever discovered. It is not possible to send all consumptives to the mountains, nor all anemic children to the seaside; but it is possible to create an atmosphere in any home that shall contain all the healing and health-giving properties of mountain air and sea breezes. And if, as it is reasonably claimed, typhoid fever can be practically eliminated from the death list, and the white plague of consumption cured, two of the greatest sources of suffering and sorrow will have been removed from civilized life.

FREIGHT CARS DELIVERED ON STREET RAILROADS.

The possibilities of the electric street railroad for freight purposes are demonstrated in the announcement of the New York Hudson River & Hartford Railroad that Providence merchants and manufacturers whose establishments are not located directly upon the line of steam roads will be given the opportunity to have freight delivered directly to their doors in the cars in which it has been hauled to the city by the steam lines. The company has now acquired the electric street railroad system of the city of Providence and its suburbs. It already controlled all the steam lines radiating from the city. The gauge of the tracks of the two systems is the same. All that will be necessary will be to replace existing rails in the street with those having the deeper grooves necessary to take the wider flanges of the wheels of the rolling stock of the steam lines. Electric locomotives will then haul freight cars from the tracks of the steam lines through the streets to the doors or yards of shippers; and, of course, freight will be collected in the same manner, giving to the manufacturer or merchant as economical conveniences in shipping as those possessed by establishments having spur tracks from the steam railroads. This traffic will be carried on in the night, when the street lines have comparatively little passenger service, and consequently no inconvenience will be caused to the public.

The advantages of such a system of freight delivery and collection are apparent. The merchant will, of course, have to pay some extra charge for delivery, covering transportation over the street lines, and the manufacturer will doubtless have to put in a spur track from the street in order that cars may be delivered into his yard. But against these costs is that of carting goods to and from a freight depot, which, it is stated, is greater than the rates that the railroad will charge for delivery by its street line.—*Iron Age.*

INDUSTRIAL DEVELOPMENT IN INDIA.

The manufacturers and exporters of the United States, when considering the trade of India must not leave out of the calculation the item of home production. If India worked up all its cotton, wool, hair, hides and skins, jute, and metals, and utilized all of the other resources that belong to its rich domain by converting them into manufactured products, there would be little left to be supplied by other countries. Despite the drawbacks that retard the progress of India it makes a fairly creditable showing in manufactures. In 1905 there were 1,336 factories run by steam that were owned by home companies or individuals. The cotton mills (186) are principally in Bombay, the jute mills (40) are in Bengal, near Calcutta, and the rice mills (121) and sawmills (71) for the most part are in Burma. The factories and mills give daily employment to 587,560 persons. Besides the mills operated by steam, water and electric power there has been a revival of the hand looms, and the output from these is double that of the mills. It requires an enormous amount to clothe the millions of people in India, who wear little except cotton the year round. The coolies and poorer classes wear the common muslins, while the higher classes wear the mulmul or high-grade muslins. The mulmuls or high-grades retail at 5 to 13 cents a yard and common muslins from 3 to 4 cents. A suit of clothes for the average poor person of India costs from 15 to 20 cents and the head gear or turban as much more. The females require more goods for a suit, but do not wear the turban.—*Washington Bureau of Manufactures.*

—According to a late official report the area sown to cotton in British India for 1906-7 crop considerably exceeds all records for previous years, and the output, it is estimated, will be unprecedentedly large.

THE PRESSED STEEL CAR COMPANY.

The eighth annual report of the Pressed Steel Car Company, covering the calendar year 1906, shows that the gross sales of the company for the year were $36,158,586.47 and the net profits were $3,381,884.18. President Hoffstot thus refers to the steel passenger car department of the company's works: "The operation of the steel passenger car shop did not contribute to your company's earnings, for the reason that education of men in a new line of industry is expensive and tedious, and full output of work cannot be secured by reason of the unfamiliarity of the workmen with the work; but we have gone far enough into this construction to know that, as a result of the operations to date, we can produce a first-class fire-proof passenger car with only a slight increase in weight over the present wooden type, but at an increased cost. The question as to how great will be the pecuniary benefit to accrue to your company from this department must be left to the future, as the railroads at the present time, when there is an urgent demand for better service and the various State Legislatures are insisting on lower rates, naturally show hesitancy in doing anything that will increase the cost of their equipment."—*Bul. Iron and Steel Asso.*

(Stated Meeting held Thursday, February 28, 1907.)

Colloidal Solution: The Intermediate State Between Solution and Suspension.

Robert H. Bradbury.

I. SOLUTION AND SUSPENSION.

When water is poured upon finely divided gold the liquid wets the metal but no further effect is visible. In the absence of external disturbance the gold will remain at the bottom for an unlimited time. This behavior is commonly described by the statement that gold is *insoluble* in water. Modern chemistry has fairly well established the thesis that entire insolubility is an ideal limiting case not actually met with. Compounds like barium sulphate, calcium oxalate and the silver compounds of chlorine, bromine and iodine have solubilities in water which have not only been detected but measured. However, *practical* insolubility is frequent so that the old term is still useful and will be retained.

Now, if the water with the gold lying at the bottom is shaken up, a temporary distribution of the metal through the liquid—a *suspension*—is produced. The only difference is that the particles of gold are very much farther apart on the average than they were before. The liquid is turbid and the gold can be separated from it by a filter. Thus the most superficial inspection shows that there are two things present, a solid and a liquid. In the language of the Phase Rule there are three phases, water, which may have taken up an extremely minute quantity of gold; gold, which may have absorbed a still more minute quantity of water, and vapor, in which only water can be detected, but in which the presence of gold may be assumed for theoretical reasons.

But the Phase Rule, which has been of such supreme service in

the treatment of heterogeneous systems in equilibrium, can give us no help in the present matter, for our suspension cannot be obtained in equilibrium. Left to itself, it instantly begins to separate—sedimentation goes on until each particle of gold has found a resting place. The suspension is dominated absolutely by gravitation. Other forms of energy play no role. The free energy which it contains is the same as that of a raised weight and can be calculated by multiplying the weight of the gold by the average fall, which would be approximately half the depth of the water.

When water is poured over copper sulphate the system conducts itself in an entirely different way. The blue color of the solid appears, first in the contiguous liquid and later in the remote. If the quantity of the sulphate is not too large, it disappears entirely; if it is in excess the liquid takes up a quantity which is always the same at the same temperature and pressure and which increases rapidly with the former and slowly with the latter. When equilibrium is reached, the distribution of the sulphate through the liquid is entirely uniform. The differences of concentration which arise during the dissolving are adjusted spontaneously by diffusion, without the intervention of any external agency. This final condition is absolutely permanent. Nothing analogous to sedimentation occurs, no matter how long a time is allowed, and so far as we know gravitation has no power whatever over the dissolved sulphate, for all attempts to establish a greater concentration in the lower portions when a long tube is filled with a solution and placed vertically, fail.

Just as the solution is the natural permanent state of the two substances—water and copper sulphate—when in contact, so the dissolving of the sulphate in the water is a self-acting, spontaneous process, which occurs without external energy being added to the system. On the contrary it reduces the free energy of the system and therefore can be made to do external work. In this work, which the dissolving process can be made to do, the driving force is the *osmotic pressure* of the copper sulphate. The sulphate tends, as we have seen, to distribute itself evenly through the liquid—it behaves like a gas which when liberated in an empty space proceeds to occupy evenly every portion of the space.

If a partition is interposed which is saturated throughout with the water but will not permit the sulphate to pass, the latter, in

its effort to expand into the rest of the liquid, will exert osmotic pressure upon the partition and if it is adjusted to move against an external resistance, work will be done. The sulphate can be placed in the bottom of a vertical cylinder filled with water and a piston which allows the water, but not the sulphate to pass, inserted. Then as the sulphate dissolves and endeavors to expand into the water above the piston, it will exert a pressure and, if the latter be weighted, the weight will be raised and work will be done.

Conversely, if, after the copper sulphate has occupied the entire liquid, the piston is burdened with a weight which is kept in excess of the osmotic pressure it will be forced downward, the sulphate will be crowded into a smaller and smaller volume of liquid and will finally crystallize.

Thus by means of a "semi-permeable" membrane it can be shown that the dissolving of a solid can be made to do work and that when the same amount of work is done upon the system the dissolved substance is again separated from the solvent.

2. THE EFFECT OF DECREASING THE SIZE OF THE PARTICLES.

It is always easy to formulate distinctions which apply to the typical members of two different classes—it is the transitional intermediate ones that are difficult to classify. For instance, one would hardly expect any difficulty to arise in deciding whether to call a given system a solution or a suspension. The distinctions seem unmistakable—

Solution.	Suspension.
1 Homogeneous.	1 Heterogeneous.
2 Clear.	2 Turbid.
3 Permanent.	3 Temporary.
4 Formed by a spontaneous process or contact.	4 Formed by external action.
5 Non-separable by filtration or decantation.	5 Separable by these means.
6 Formation liberates energy and can produce work.	6 Formation absorbs energy.

Starting with matter in a state of coarse mechanical suspension in water let us imagine the size of the particles gradually to decrease. We shall find that the above criteria fail us and that it becomes almost impossible to decide whether we are to call the system a solution or a suspension.

By powdering in a mortar or similar mechanical means sub-

stances can be pulverized until the average diameter of the grain is $\frac{1}{4}$ of a micron.* Any substance, unless it happened to have the same refractive index as water, would produce a strong turbidity easily visible to the naked eye if the particles were as large as this. But we may anticipate that when the particles became very much smaller than the wave-length of light they might cease to reflect in such a way as to show their presence to the unaided vision. Now the wave-lengths of the visible frequencies of light are grouped between 1 micron and 0.1 micron. Therefore we might predict that somewhere about the diameter of 0.1 micron the particle would no longer render the liquid turbid to the unaided eye. This prediction is in full accord with experiment. Measurements of the size of the particles are difficult and few, but in the case of gold the limiting size of the particle-producing turbidity is about 0.1 micron—probably less. From the high density of gold and its behavior toward light we should expect it to produce turbidity with a smaller particle than other substances. So far as I am aware, exact measurements of the size of the particles in colloidal solutions of oxides, hydroxides, sulphides and organic colloids have not been made, but it is a safe statement that a much larger particle than 0.1 micron is required to make the solution turbid. Work is going on actively in this field and we may expect definite results in the near future.

Are we to call this clear liquid containing finely divided metallic gold a solution or a suspension? The most natural reply is that there has been no change in principle—the delicacy of the eye has failed us, that is all. Since the liquid still contains particles of gold distributed through water, it is a suspension.

It is true that the microscope will enable us to detect particles decidedly smaller than 0.1 micron floating in a liquid, but there is a far more powerful instrument for this purpose. Everyone has noticed that when a beam of light enters a dark room through a chink in the shutter the floating motes of the air spring into plain visibility. Tyndall was the first to call attention to the possibilities of the light-beam in detecting suspended matter. That the effect is really due to motes and not to the air itself can be demonstrated by a familiar lecture experiment. The inside of a glass box is smeared with glycerine and it is allowed to stand

*A micron is .001 millimeter.

over night. The solid matter settles and then when the beam is sent through there is no trace of its passage—the box is "optically empty." The purest distilled water contains countless floating particles and it is difficult to eliminate them, so difficult that until recently it was an open question whether the water molecules themselves did not disperse the light,. but Spring has shown that if a little zinc hydroxide is precipitated in it the suspended matter is all carried down and the water becomes optically empty.

Now if we focus an image of a powerful arc, or better, of the sun, in the liquid and examine it under the microscope, making provision for the prevention of any accidental light reaching the eye, we have the *ultra-microscope* of Siedentopf and Zsigmondy. This is an instrument of wonderful power in the investigation of the infinitesimal, and to it the recent great advance of our knowledge in this direction is largely due. With it particles as small as 5 millimicrons* can be *separately seen* and particles much smaller—how much smaller no one knows—can be detected by the visibility of the cone of light. By means of it all gold solutions down to and somewhat beyond 5 millimicrons can be shown to contain their gold in the solid form. This brings us in the midst of the domain of the infinitely little. The smallest particle which can be seen separately is only about $\frac{1}{100}$ of the dimensions of the smallest visible light wave and only 50 times the diameter assigned by van der Waals, Exner and others to the molecule of hydrogen (0.1 millimicron). The smaller particles which cannot be seen separately, but still reflect the light and polarize it, cannot contain more than a few molecules, but they must contain more than one, for there are other gold solutions still more finely divided which give no light cone at all—are optically empty—and yet are identical in their other properties.

Liquids containing solids in this condition of excessive subdivision have received the name of *colloidal solutions.* The facts just discussed have led some chemists† to regard them simply as suspensions of great fineness. But the matter is not so simple as this and before settling it in this off-hand way we ought to inquire how true solutions behave toward the cone of light.

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*A millicron is .001 micron = .000001 millimeter.

†Stöckl & Vanino. Zeitschr. Pysikal. Chem. 30, p. 98 (1899).

Spring† and Lobry de Bruyn‡ have done some interesting work upon this point which has not attracted as much attention as it deserves. The results briefly are as follows: Solutions of salts of K, Na, Ca, Sr, Ba, Zn, Mn, Co, Ni, Cd are optically empty, but water solutions of chlorides, nitrates or sulphates of Al, Cr, Fe^{III}Cu and Pb show the passage of the beam strongly. Spring has attributed this to hydrolysis producing a colloidal solution of the hydroxide and his explanation is supported by the facts that the solutions in question redden litmus and that hydrochloric acid weakens the cone and, in sufficient quantity, causes it to disappear. However, true solutions of high molecular weight, for instance, ordinary sugar, raffinose, phosphomolybdic acid and the benzoyl esters of mannite and dulcite, show the effect strongly.

Starting with the molecular theory, it is clear that the homogeneity of any solution is only apparent and detecting solid matter in it is a question of delicacy of method. Van Calcar and Lobry de Bruyn placed solutions—e. g. of KI, KCNS, Na_2SO_4—in a centrifugal machine making 2400 turns per minute. The experiment was arranged so that at the end of the centrifugation the liquid was contained in four different compartments. The dissolved substance was contained chiefly in the solution from the outer compartment. From a 9% solution of Na_2SO_4 about one-third crystallized in the outer compartment.

It seems, therefore, that using the utmost refinement of experimental method we can prove that colloidal solutions are heterogeneous and therefore turbid, but it also appears that if we called them mere suspensions on this account we should have to treat most true solutions in the same way—the conception solution would disappear from science.

We may also note the fact that a colloidal solution is permanent so long as the fineness of subdivision persists. Sedimentation takes place in many cases, but it is always preceded by the union of many of the smaller particles to larger ones—a kind of coagulation. There are various ways of preventing this, and so long as it is prevented, the distribution remains uniform. Gravitation does not determine the sequence of events. It has retired

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†Bulletin Acad. Royale Belg., 1899, p. 300.

‡Rec. Travaux Chimiques des Pays Bas, 23, p. 155 (1904).

into the background, as we shall see later, in favor of kinetic energy, surface energy and electrical phenomena. It follows, of course, that the solid cannot be separated from the liquid by decantation. Ordinary filtration is completely without effect.

We have now seen the justification for collecting these substances in a class by themselves. Naturally it is not easy to define the exact boundaries which separate them from true solutions on the one side and suspensions on the other. Probably there is no exact line of separation, the classes merging into each other. We shall take up this point later.

3. THE COLLOIDAL SOLUTION OF GOLD.

Preparation. The first necessity is doubly-distilled water of special purity. For the second distillation a silver condenser must be used. Access of air or contact with a ground glass stopper will charge it with solid particles and make it useless. It is kept in bottles stoppered with corks wrapped in tinfoil. When the electric arc is allowed to burn between two gold wires under this water the metal is obtained in very fine division on account of the sudden cooling of the vapor, and a colloidal solution is produced. This method is due to Bredig and it applies also to Pt, Pd, Ag and many other metals.*

The other general method is by the reduction of an extremely dilute solution of gold chloride with formaldehyde at a boiling temperature or with an etherial solution of phosphorus in the cold. If the experiment succeeds the liquid is bright red and entirely clear. In some cases the gold particles are so small that even the ultra-microscope fails to detect them. Sedimentation does not occur so long as coagulation is prevented. Under favorable circumstances if the water used was pure and freezing is not allowed, the solutions are practically permanent. In those prepared by the arc the subdivision is not so fine. They are purple-red or violet, and somewhat less stable.

The favorable effect of great dilution of the $AuCl_3$ in chemical reduction is easily understood. In a strong solution the minute particles first formed find abundant dissolved gold in the liquid and grow at the expense of it until glittering flakes of gold

*Colloidal solutions of K, Na, Li, Rb and Cs in anhydrous ether have been made by a similar method.

are produced and sedimentation occurs. But when the quantity of gold in each c.c. is very small the production of the first sub-microscopic particle exhausts it and growth is impossible.

Properties. As already stated, the subdivision is so extreme in some solutions that the light cone is scarcely visible in the ultra-microscope. Particles slightly larger produce a cone which cannot be separated into individuals. That these liquids really contain colloidal gold and not some red compound of the metal can be proved by adding a solution of almost any soluble acid, base or salt—any electrolyte—when the color of the liquid changes to blue and the particles in the cone at once become visible. From about 5 millimicrons upward the particles are separately visible. They are brightly colored—green, red or yellow. Some solutions contain only green particles, some only red, some only yellow and in still others all three are present. Naturally, the color of the liquid by transmitted light is complementary to that of the particles it contains. The red solutions contain chiefly green particles, the violet yellow ones. It is impossible to predict the size of a particle from the color. All three occur in widely different dimensions, but on the whole the green are the finest and the yellow the coarsest.

The particles are in continual motion, the smaller ones moving most rapidly. Zsigmondy* compares the appearance of the light-cone to a swarm of gnats in the sunlight. The motion of the smallest particles can be resolved into two components. There is a direct progression in which the particle covers from 1,000 to 10,000 times its own length in a second and an oscillation of very short period. The progressive movement is zig-zag and variable, so that a particle after describing a zig-zag, each line of which is 100 to 1,000 times its own diameter and taking perhaps $\frac{1}{8}$ of a second for each, will rush quite off the field of view in a straight line. This motion shows no decrease with time. Solutions more than a year old exhibit it just as actively as at first, unless coagulation has begun.

It is natural to expect some connection between the heat and light which are projected into the liquid and the motion of the particles. On this point Zsigmondy calls attention to the facts:

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*Zur Erkenntnis der Kolloide, p. 107. This book is an excellent monograph on the colloidal gold solutions.

1. That when a water chamber is interposed the motion is unaffected. 2. That there is no relation between the direction of motion and the direction of light. 3. That the motion is independent of the length of time the beam has acted. When the beam is suddenly shifted to a new part of the liquid which has been in darkness the motion is found to be quite as active. 4. That the motion is independent of the intensity of the light, being just as active in the wider parts of the cone as at the focus and just as active when electric light is employed as by sunlight.

The cause of this most interesting phenomenon is obscure. It may be electrical in nature—all the particles are negatively charged. But it must be recalled that these masses can contain only a few molecules. The fact that the motion greatly increases with decreasing size of the particle may indicate that we are here observing the kinetic energy of the molecule which we call heat.

The method by which the size of the particles is ascertained is interesting. Of course direct measurement is absolutely out of the question. The quantity of gold in each c.c. of the liquid is known from the weight of gold chloride used in making it. Dividing this by the density of gold which may be taken as 20 we obtain the volume of the gold in the unit of volume of the liquid. The ultra-microscope has an attachment—an ocular micrometer—by means of which the volume of the illuminated portion of the liquid can be determined. Thus the total volume of gold in the light cone becomes known. If the liquid is so diluted that the number of particles is not too great, they can be counted and by division the volume of each particle is obtained. The cube root of this gives the diameter on the assumption that the particle is a cube. Putting this into a formula we have

$$D = \sqrt[3]{\frac{M}{20\ N}}$$

where D is the diameter sought

M the weight of gold in the light cone

N the number of particles.

There is no reason to think that the particles are cubical, but some shape must be assumed and the effect on the result would be small. It is clear that the figure obtained is an average simply. The error does not exceed 20%.

When a solution of any electrolyte—common salt answers

well—is added to a red colloidal gold solution, the color changes to blue and the gold collects in larger particles. Thus a bright-red solution so finely divided as scarcely to show the track of the beam was placed in the ultra-microscope and sodium nitrate solution added.* The light-cone became visible, moving spherical yellow cloudy masses appeared in the liquid. The clouds condensed to numberless minute particles in violent motion. These particles in turn coalesced to larger ones which moved, but more slowly than before.

Where the gold solution is pure this change is irreversible—the gold once coagulated cannot be restored to solution except by converting it into gold chloride and repeating the reduction. All colloidal metals and most oxides and sulphides act in the same way and are called *irreversible* colloids. On the other hand, dextrin, gum arabic, gelatine and most kinds of albumin when separated from water can again be dissolved in it and the separation and re-solution repeated an unlimited number of times. Such substances are called *reversible* colloids. It is an interesting fact that in presence of a reversible colloid, like gelatine, the coagulation of gold becomes reversible. Thus, if gelatine is added to a colloidal gold solution and the mixture allowed to evaporate on a glass plate, it coagulates to a blue or violet mass. This is composed of larger units, but the gold particles have not coalesced. Compound particles containing from a hundred to a thousand gold particles imbedded in gelatine have been formed. They seem to contain equal volumes of gold and gelatine and of course are very much richer in gold by weight. When heated with water the gold particles are again disseminated and the colloidal solution is reproduced. The addition of a small quantity of gelatine or some other reversible colloid to a gold solution will entirely prevent the coagulation by electrolytes and the consequent change in color from red to blue. Different colloids exhibit great differences in the quantity required to produce this protective action. Thus gelatine is, weight for weight, about 20 times as effective as egg-albumin and about 100 times as efficient as gum arabic.

4. We may now return for a moment to the distinction between colloidal solutions and true solutions on the one side and

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*Zsigmondy, p. 115.

true suspensions on the other. This is a most interesting and important question, but investigation has not gone far enough to return a complete answer to it.

The greatest difference between true crystalloidal solutions and colloidal solutions is the lack of the osmotic energy of volume which practically determines the behavior of the latter. Hence a colloid exerts little or no osmotic pressure and no external work is afforded by the process of dissolving it. For the same reason the freezing and boiling points are sensibly identical with those of the pure solvent. Another aspect of the same fact is that the force which holds solvent and colloid together is far weaker than in the case of an ordinary solution. Their separation is easier.

Another important difference is the behavior toward the electric current. A crystalloidal solution is either a non-conductor—like sugar—or else it is dissociated into ions which transport equivalent amounts of electricity to both poles. But a colloid all migrates either to one pole or the other—usually to the anode—although some, like the hydroxides of iron, aluminum, chromium, thorium, zinconium and cerium pass to the cathode. Accordingly the particles in most colloidal solutions must be negatively charged and this is in agreement with experiments which show that when two substances are brought into contact the one with the highest dielectric constant is charged positively and the other negatively. Owing to the very high dielectric constant of water (80) most substances would be charged negatively on contact with it.

Lack of optical homogeneity is another distinction, but we have seen that many true solutions show the same phenomenon.

There is nothing in crystalloidal solutions corresponding to the *coagulation* of colloids. This distinction holds good whether we consider the turning of the red gold solutions to blue with simultaneous coalescence of the particles or the setting of other colloids to a jelly, as in the case of gelatin, alumina and silicic acid.

When a solution of a positively charged colloid like stannic acid is mixed with one in which the particles have a negative charge, like gold, then, if the proportions are correct. electrical neutralization occurs and both precipitate in an extremely intimate mixture. In this particular case the precipitate is "purple

of Cassius," which is mixed colloid of stannic acid and gold.

Among the distinctions between colloidal solutions and suspensions we have in the first place the immensely fine division of the solid.*

Then the settling of a suspension is a reversible process. One can always shake it up and distribute the solid again in the liquid. The irreversible coagulation of some colloids and the setting of some to jellies are without good analogies among the suspensions, though these are suggestive phenomena in the coalescence of fine particles in suspension which sometimes precedes settling.

The coagulation of a colloid may liberate considerable quantities of energy. Thus when a gram atom of colloidal silver coagulates something like 27,000 cal. are set free, and when the precipitated jelly turns to ordinary silver there is a further liberation of about 6,500 cal. This is a most important distinction between colloidal solutions and suspensions and is of itself a complete justification for making them a separate class, for the trifling amount of gravitational energy which is set free in the settling of a suspension could not be measured in any colorimeter.

5. GENERALITIES.

In the main, the chemist in the enormous development of his science during the 19th century proceeded from crystal to crystal. The analytical chemist has been forced—much to his discomfort—to occupy himself somewhat with colloidal matter—for instance, in the case of silica and some sulphides—while the organic chemist has started with materials purified by re-crystallization, has purified his products in the same way and has thrown everything which could not be induced to crystallize under the head of tarry side products, "Schmieren." The chemist has devoted himself essentially to the crystalloids and this was a necessary specialization. The vast advance which has been made is an effective answer to anyone who would criticize the point of view. But as we have seen, the problem of colloidal matter has now been attacked and much more than a beginning has been made. The new science is not only born but is in sound, vigorous and wonderfully rapid growth. In it the simple and

*Zsigmondy. Zur Erkenntnis der Kolloide, p. 11.

beautiful laws which have guided so surely the development of the classical chemistry must be set aside. Possibly the stochiometric laws themselves are merely the result of the limitations upon possibility which are set up by the enforcement of a definite arrangement of the molecules in the crystal. This bold suggestion is due to Lottermoser. An obvious objection is that the stochiometric laws apply to liquids and gases in which there is no definite molecular arrangement. But they certainly do not apply to colloidal compounds. If I have a salt solution and am certain that it contains no other compound of sodium or of chlorine I can determine the chlorine and calculate the sodium with the utmost exactness. The analogous calculation is impossible with a colloidal compound. In a sample of purple of Cassius both the gold and the stannic acid must be determined, for their percentage may vary within wide limits and with the variation occurs a continuous alteration in properties. Much interesting work has been done by Sabanajeff and others upon the molecular weights of dissolved colloids. The figures obtained are enormous—50,000 for silicic acid. But it is doubtful how much reliance to place upon them, for the fundamental assumption that the van't Hoff-Raoult laws apply to colloidal solutions is extremely questionable. It is very uncertain that the slight observed depressions of the freezing point were really due to the dissolved colloid. When "silicic acid" is made from sodium silicate and hydrochloric acid the jelly obstinately retains sodium chloride Even when washed with hot water until most of the jelly has dissolved and the chlorine reaction has long been absent in the washings, appreciable quantities of salt are still present. This obstinate retention of traces of other substances is an undesirable colloid characteristic which has long been familiar to the analyst. Thus the trifling observed depressions and indications of osmotic pressure may be accounted for and the basis for the calculation of the molecular weight disappears.

This same fact, the formation of a compound undecomposable by water, accounts for the astounding poisonous action of infinitesimal quantities of silver, mercury and notably copper on plant cells. The albumin absorbs the copper, forming an irreversible colloidal compound, and so it happens that copper in a dilution of 1 : 1,000,000,000 will damage and finally kill organ-

isms upon which HCN 1 : 1000 (a million times as concentrated) has no appreciable effect.

I have already trespassed far too long upon your attention. It would be interesting to discuss in detail the applications, both scientific and industrial, of our subject, but this alone would furnish material for many lectures. Physiology is concerned chiefly with colloids. Enzymes are in colloidal solution, and their peculiar activity is the result of the enormous surface exposed owing to the fine division. In the dyeing industry the fibres are typical colloids and many of the dye-stuffs are in colloidal solution. In photography the gelatin and albumin of plates, films and paper are colloids and the silver haloids are at first in colloidal solution and separate in crystalloidal state during the ripening. The modern industry of high explosives works with colloidal matter. Colloidal metals are employed in the preparation of filaments for the incandescent lamp. The decomposable matters of sewage are mainly in colloidal solution, negatively charged like most colloids and the use of iron compounds in coagulation is an instance of the electrical neutralization and mutual precipitation of two oppositely charged colloids, the positive colloid being ferric hydroxide. The colloids now have a journal devoted entirely to their interests. It is not extravagant to express the hope that the expansion of this subject may in time produce an organized body of knowledge which will equal in scientific interest and practical importance the chemistry of crystalline matter.

Book Notices.

PUBLICATIONS RECEIVED.

The Submarine *versus* the Submersible, by Simon Lake. 13 pages, plates, 8vo. Reprinted from Journal of the American Society of Naval Engineers, May, 1906.

Report of the Commission of Education for the year ending June 30, 1904, volumes i and ii. 2480 pages. Washington. Government Printing Office, 1906.

The Transit, 1906. Published annually by the Engineering Society of the University of Iowa. 64 pages, illustrations, plates, portraits, 8vo. Iowa City, Iowa.

Pennsylvania State Department of Agriculture. The Monthly Bulletin

of the Division of Zoology, vol. iv, No 2. June, 1906. Harrisburg. State Printer, 1906.

Pennsylvania State College Agricultural Experiment Station. Bulletin No. 78. A test of commercial cultures for legumes. 13 pages, 8vo. State College, July, 1906.

Report of Tests Upon Sand-Lime Bricks. By Ira H. Woolson, E.M. Reprint from "Proceedings of the Second Annual Convention of the National Association of Manufacturers of Sand-Lime Products," held in Detroit, Mich., December 5, 6 and 7, 1905. 35 pages, illustrations, plates, 8vo.

University of Cincinnati. Illustrated booklet. Unpaged, illustrations, 24mo. Cincinnati, 1906.

Asbestos Protected Metal Company. Booklet describing asbestos protected metal. 23 pages, 12mo. Canton, Mass., 1906.

Universal System of Machine Moulding. Ph. Bonvillain & E. Ronceray, Paris-Aubervilliers, patentees and makers. 35 pages, illustrations, 8vo.

United States War Department, Annual Reports for the fiscal year ended June 30, 1905. Vols. 10, 11, 12, 13 and 14. Washington. Government Printing Office, 1905. 5 volumes, illustrations, plates, 8vo.

Chicago Pneumatic Tool Company. Catalogue No 20. Franklin Air Compressors, pneumatic tools and appliances. 116 pages, illustrations, 8vo. Chicago, 1906.

List of books on Steam and Gas Engines, published by the Brooklyn Public Library. 23 pages, 16mo. Brooklyn, 1906.

Was sind und wie enstehen Erfindungen? Eine entwickelungstheroretische Studie von Ingenieur Josef Löwy, Mitglied des K. K. Patentamtes in Wien. 18 pages, 8vo. Wien, A Hartleben, 1907.

U. S. Geological Survey. Mineral products of the United States, calendar years 1896 to 1905. Folded sheet. Washington. Government, 1906.

Cornell University. The President's Report 1905-1906. 50 pages, 12mo. Ithaca, N. Y., University, 1906.

Providence, R. I. Annual Report of the City Engineer for the year 1905. 80 pages, illustrations, 8vo. Providence. City printers, 1906.

Rivetage par M. Fricker. 168 pages, illustrations, 12mo., Paris, Gauthier-Villars, n. d.

The above volumes are the latest additions to the well-known series Encyclopédie Scientifique des Aide—Mémoire issued under the editorial direction of M. Léauté. The books are uniform with previous issues and form valuable monographs on the subjects to which they relate. They cover a wide field and are written by specialists in the various branches. The price is two francs, 50c. in paper, and three francs in cloth. R.

Sections.

Electrical Section.—*Stated meeting*, held Thursday, February 21st, at 8 P.M. President Thomas Spencer in the chair.

Dr. Lee de Forest presented a paper on "The Development of Wireless Telegraphy," which was fully discussed by the members present. A vote of thanks was passed to the speaker and the meeting adjourned.

Richard L. Binder, *Sec'y.*

Stated meeting, held Thursday, April 11th, at 8 P.M. President Spencer in the chair. Present, seventy-eight members.

Dr. Henry Leffmann presented a paper on "Electrical Methods Direct and Indirect for the Purification of Water," which was fully illustrated by specimens and slides. The paper was discussed by Drs. Goldsmith, Wahl, Williams and Messrs. Colvin, Hering, Spencer, Cameron and others. A vote of thanks was passed to the speaker of the evening and the meeting adjourned.

Wm. H. Wahl, *Sec'y pro tem.*

Mining and Metallurgical Section.—*Stated meeting*, held Thursday, January 17th, at 8 P.M. Dr. Wahl in the chair. Present, thirty-eight members.

Prof. Angelo Heilprin presented a paper, fully illustrated, on "The Interrelation Between Earthquake and Volcanic Phenomena." The thanks of the meeting were voted to the speaker and the meeting adjourned.

Wm. H. Wahl, *Sec'y pro tem.*

Stated meeting, held Thursday, January 31st, at 8 P.M. Mr. Clamer in the chair. Present, fifteen members.

Dr. William Campbell presented a paper on "The Microscopic Examination of Certain Sulphides." The thanks of the meeting were voted to the speaker and the meeting adjourned.

Wm. H. Wahl, *Sec'y pro tem.*

Section of Physics and Chemistry.—*Stated meeting*, held Thursday, January 17th, at 8 P.M. Dr. Wahl in the chair. Present, thirty-eight members.

Prof. Heilprin presented a paper on "The Interrelation of Earthquake and Volcanic Phenomena," which was fully illustrated. A vote of thanks was passed to the speaker and the meeting adjourned.

Wm. H. Wahl, *Sec'y pro tem.*

Stated meeting, held Thursday, February 28th, at 8 P.M. Dr. H. F. Keller in the chair. Present, twenty-five members.

Dr. R. H. Bradbury presented a paper on "Collodial Solution, the Intermediate state between Solution and Suspension." The paper was discussed by Drs. Keller and Williams and Messrs. Hering and Spencer. The thanks of the meeting were voted to the speaker of the evening and the meeting adjourned.

Edward A. Partridge, *Sec'y.*

Stated meeting, held Thursday, March 28th, at 8 P.M. Dr. Bradbury in the chair. Present, fifteen members.

Dr. J. Merritt Matthews presented a paper on "The Theory of the Dyeing Process," which was discussed by Drs. Goldsmith, Williams, Bradbury and Mr. Colvin. The thanks of the meeting were voted to the speaker and his paper recommended for publication in the *Journal.* Adjourned.

W. J. Williams, *Sec'y pro tem.*

Mechanical and Engineering Section.—*Stated meeting,* held Thursday, January 17th, at 8 P.M. Dr. Wahl in the chair. Present, nineteen members.

Prof. Angelo Heilprin read the paper of the evening on "The Interrelation of Volcanic and Earthquake Phenomena," which was fully illustrated. The thanks of the meeting were tendered to the speaker and the meeting adjourned.

Wm. H. Wahl, *Sec'y pro tem.*

Stated meeting held Thursday, February 7th, at 8 P.M. President Charles Day in the chair.

The paper of the evening was by Mr. J. C. Irwin, of New York, on "Signal System on the New York Central and Hudson River Railway." In the absence of the author it was read by Mr. Day. The paper was illustrated, and was discussed by the members, and was referred for publication. Adjourned.

Francis Head, *Sec'y.*

Stated meeting, held Thursday, March 7th, at 8 P.M. Prof. Lewis M. Haupt in the chair. Present, forty members and visitors.

The paper of the evening was read by Mr. Paul T. Warner on "The Modern Locomotive," which was fully illustrated and discussed by Messrs. Colvin, Haupt and Johnson.

After a vote of thanks to the speaker the meeting adjourned.

Francis Head, *Sec'y.*

Section of Photography and Microscopy.—*Stated meeting,* held Thursday, January 17th, at 8 P.M. Dr. Wahl in the chair. Present, thirty-eight members.

Prof. Heilprin presented a paper on "The Interrelation of Earthquake and Volcanic Phenomena," which was fully illustrated. A vote of thanks was passed to the speaker and the meeting adjourned.

Wm. H. Wahl, *Sec'y pro tem.*

Stated meeting, held Thursday, April 4th, at 8 P.M. Prof. Lewis M. Haupt in the chair. Present, thirty-five members and visitors.

Dr. Edward Goldsmith gave an informal talk on "Observations on a Recent Trip to the Windward Islands." The subject was illustrated by lantern slides. At the conclusion of the speaker's remarks the subject was discussed by some of the members. A vote of thanks was tendered to the speaker of the evening and the meeting adjourned.

Louis E. Levy, *Sec'y pro tem.*

The Franklin Institute.

(Proceedings of the stated meeting held Wednesday, February 20, 1907.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, February 20, 1907.

PRESIDENT WALTON CLARK in the chair.

Present, thirty-two members and visitors.

Additions to membership since last report, ten.

The President introduced Dr. Chas. F. Himes, who presented a communication on "The Preservation of Written Historical Documents," and illustrated his remarks by showing a document reinforced with silk gauze, where its fold had worn through by reason of much handling, and explained a method of successfully applying the reinforcing materials.

Mr. W. C. L. Eglin, of Philadelphia, addressed the meeting on "High Efficiency Incandescent Lamps." The lecture hall being brilliantly lighted for the occasion by replacing the usual incandescent lamps with those of the variety known as the "Tantalum" lamp. An interesting discussion followed, which was participated in by Messrs. Hammer, Eglin, Heany, Clark and Dr. Meeker.

Mr. R. A. Smith, of Philadelphia, brought to the attention of the meeting a new chemical compound, "Oxodium," and, assisted by Mr. C. C. Balderston, gave a demonstration of generators used for producing pure oxygen gas from Oxodium, and described the various uses of the compound in submarine boats, tunnels, mines, etc. The subject was discussed by Drs. Himes, Williams, Meeker and Messrs. Hammer, Balderston, Stratton and others.

The President expressed the thanks of the meeting to the speakers of the evening. Adjourned.

H. L. HEYL, *Sec'y pro tem.*

(Proceedings of the stated meeting held Wednesday, March 20, 1907.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, March 20, 1907.

PRESIDENT WALTON CLARK in the chair.

Present, eighteen members.

Additions to membership since last report, ten.

The President announced the appointment of the standing committees of the Institute for the year 1907.

The President then introduced Mr. James Howard Bridge as the speaker of the evening, who presented a communication on "Ozone: Its Nature, Production and Uses." The speaker illustrated his remarks by the exhibition of an ozone producing apparatus of special design and construction. On motion, the subject was referred to the Committee on Science and the Arts for investigation and report.

Mr. H. Clyde Snook, of the Roentgen Mfg. Co., gave an interesting

talk, illustrated by lantern slides, showing diagrams of the variations in vibrations in the production of the Roentgen Rays under varying conditions.

A vote of thanks was passed to the speakers of the evening. Adjourned.

H. L. HEYL, *Sec'y pro tem.*

(Proceedings of the stated meeting held Wednesday, April 17, 1907.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, Pa., April 17, 1907.

PRESIDENT WALTON CLARK in the chair.

Present, eighty-two members and visitors.

The report of the Board of Managers showed an addition of five persons to the membership since last report.

President Clark made an announcement of the fact that the Board of Directors of City Trusts had voted to appropriate the Franklin Fund to the Franklin Institute for the purpose of erecting a new building as a memorial to Benjamin Franklin. The President stated that further details of this subject would be presented at a later meeting.

The President thereupon stated that Messrs. Dodge and Day had made arrangements to have Prof. V. Karapetoff, of Cornell University, deliver an address on "The Human Side of the Engineering Profession" before a gathering composed of their engineers in conjunction with the regular meeting of the Franklin Institute in order that Prof. Karapetoff's address may be delivered before this meeting. The President thereupon vacated the chair to give place to Mr. Conrad A. Lauer, representing the Engineers' and Constructors' Society, who then introduced Prof. Karapetoff as the speaker of the evening.

At the close of the lecture the subject was thrown open for discussion, in which Messrs. James M. Dodge, H. F. J. Porter and President Walton Clark participated.

On motion of Mr. Chas. Day, seconded by Mr. Kern Dodge, the thanks of the meeting were unanimously voted to the lecturer and the meeting was adjourned.

WM. H. WAHL, *Secretary.*

THE BOARD OF MANAGERS.

(Extract from the minutes of the Board meeting, held Wednesday, February 13, 1907, relative to the retirement of Mr. John Birkinbine as President.)

At the stated meeting of the Board of Managers held February 13th, 1907, the following minute upon the retirement of Mr. John Birkinbine from the presidency of the Institute was adopted:

"WHEREAS, The services of Mr. Birkinbine as Chairman of this Board has been terminated by his retirement from the office of President of the Institute, be it

"*Resolved*, That his colleagues of the Board of Managers, fully cognizant of the unremitting efforts devoted to the interests of the Institute by Mr. Birkinbine throughout the ten consecutive years of his varied serv-

ices as its President and as Chairman of the Board, hereby record their appreciative recognition of the great value of those services in the promotion of the Institute's activities; and be it further

"*Resolved*, That this minute be published in the *Journal* of the Franklin Institute and an engrossed copy thereof transmitted to Mr. Birkinbine."

Attest: H. L. Heyl, *Actuary*.

Annual Reports of the Schools of Drawing, Machine Design and Naval Architecture for the Sessions of 1906-1907.

The Drawing School.—This school has had a very satisfactory season in the work that has been done and the progress that has been made, although the number of students was somewhat less than last year. What is taught here forms the best possible introduction to all mechanical pursuits, and should be taken advantage of by everyone whose tastes lie in that direction, or who is already at work making things. Things cannot be made without being planned, either by the maker or by someone else, and the only successful and economical way of planning is to put the conception upon paper in such manner that the shape and size of all the details harmonize with the intended purpose. Without this, modern civilization would be impossible. Hence the great importance to everyone connected with mechanical production and advancement, of the knowledge of the principles and a fair amount of skill in connection with graphic analysis and mechanical drawing. Cut-and-try methods are passed. Modern system and organization require that inventions, structures, and designs be worked out fully on the drawing board before any material is used or work employed. Besides, the gathering of the material and the work upon it are governed by the drawing, so that a good knowledge of drawing is essential to any one who would take a responsible position in connection with it. The study is not intended alone for those who wish to become draughtsmen, but is important to all those who hope to be of much account in any of the practical departments.

The Following Students have Deserved Honorable Mention:

In the Senior Mechanical Class.

Louise Fithian,
Walter Saatman,
William Undercoffer,
Herman Karsch,
Howard G. Balz,
Charles W. King,
Alvin Hatfield,
Frank Regnault,
James F. Fennell.

In the Intermediate Class.

George F. Johnson, Jr.,
Craig Annê,
Amos E. Temple,
Theodore Richter,
Edward F. Parsons,
Arthur V. Conover,
Ralph Barnum,
Eugene Heckel,
David H. Trego,
Otto Schaaf,
Howard Reeder.

In the Junior Mechanical Class.

Stanley K. Weber.

In the Architectural Class.

William A. Markert,
John M. Cromwell, Jr.,
Richard D. Tifft,
George M. Croll.

In the Free Hand Class.

David Bowers,
John J. Draffan.
Carl Ulrich.

The Following Students are Awarded Scholarships from the B. H. Bartol Fund:

Eugene Heckel,
George F. Johnson, Jr.,
Arthur V. Conover,
William A. Markert,
Richard D. Tift.

The Following Students, Having Attended a Full Course of Four Terms, with Satisfactory Results, are Awarded Certificates:

Walter Saatman,
James F. Fennell,
Charles W. King,
James S. Cassel,
Clarence G. Stallman,
Joseph M. Schneider,
Howard G. Balz,
Henry Hagstrom,
Clayton H. Robson,
Carl Ulrich,
William Undercoffer,
Clifford V. Raffo,
Henry Schwemmer,
Louis C. Haug,
Frank Butler,
Thomas McLoughry,
Joseph O'Keefe,
John A. Schaffer,
Hilton Le Roy,
Archie Ritchie,
William S. Brown.

The Branch Drawing School.—The season of 1906 and 1907 closes with the Branch Drawing School having an attendance larger than any season in its history, and we are now limited by the size of our school room, 17th and Venango Streets, being unable to meet the demand made upon us for instruction.

The intelligence of the students attending has been higher than any time in the past, and they have manifested an unusual interest in their work.

The grade of the work accomplished is all that can be expected, a high standard of understanding of the principles of mechanical drawing, neatness and speed being attained. The eagerness of the students to thoroughly learn their trade, coupled with the encouragement of the employers who have sent their young men to the school, has been an incentive to

persevering energetic work by the instructors, with a result that is particularly pleasing to the management.

Thanks are especially due to the Midvale Steel Co. and the Geo. V. Cresson Co., for their coöperation in the maintenance of the school. With a continuance of this coöperation we hope to improve still further in the work we have undertaken.

In conclusion I wish to say to the graduating scholars that I wish them all success in their undertakings, and that they will find the instruction they have secured at the Franklin Institute Branch Drawing School of Tioga a great benefit, which will re-pay them many times for their labors in obtaining it.

H. Roy Stacks,
Director.

The Following Students, Having Completed the Full Course of Four Terms, are Awarded Certificates:

Harry Billger,	Martin J. Burns,	Albert Grant,
Percy Gee,	Ross M. Kurtz,	Eugene Lyons,
Weston Mattis,	Edward Merriam,	Harry Oberheidt,
Frank Uhl,	Edward J. Danks,	Charles Deal,
Truman Hayhurst,	Harry Huber,	Harry Pennepacker.
Benjamin Stevens,		

The School of Mechanical Design.—The attendance in the several classes has been practically the same as last year. Our graduating class has been reduced in number, owing to the illness of some members, while others left the city and could not finish the course.

The usual ground has been covered in Mathematics and Strength of Materials. In connection with the work in Machine Design the students have designed and drawn a five-ton pillar crane, which was done in a very satisfactory manner, considering that all the drawing was done at home after working hours.

At the invitation of Dr. Stine, in charge of the Engineering Department of Swarthmore College, we spent one afternoon in the testing laboratories of Swarthmore College, and showed in a practical way how to find some of the values used in strength of materials. Of course, in the length of time at our disposal, we could only touch on this phase of the work. If the Franklin Institute could invest a small amount of money in laboratory equipment for the Engineering School it would aid us very materially in our work.

It is gratifying to notice that a number of graduates from the Manual Training Schools of the city, and from Girard College enter the classes in Mechanics and Strength of Materials, having had the required mathematics. We believe that if we had some systematic method of calling the attention of such students to the work done here it would result in a large increase in attendance and the general usefulness of the school.

We propose to make a few changes in the work of the school next year, in order that the course may be a little more practical than it is at present. The course in Kinematics will be given as a series of lectures, having a

standard book on the subject as reference, and our text-book on Machine Design will be changed to one more suitable to the course given.

L. M. ARKLEY, *Director.*

The following students have deserved honorable mention:

In Machine Design and Kinematics of Machines.

St. Phalle. F. de, Aroson, S. G.

In Strength of Materials.

Laherrere, Louis, Stokes, Percy,
Hatfield, Aloise, Forstrand, A.

In Trigonometry.

Davis, W. A. Gardiner, E. C.,
Donahue, R.

In Geometry.

Davis, W. A., Petri, A. H,
Donahue, R., Fennel, J. T.

In Algebra.

McDade, A. H., Greiner, H. L.,
Baumgartner, W., Paris, W E.

The following students have successfully passed their examinations, their names being arranged in order of merit:

Machine Design and Kinematics of Machines.

1 St. Phalle, F. de,
2 Aroson, S. G.,
3 Ruch, H. J.

Mechanics.

1 Laherrere, L,
2 Hatfield, A,
3 Stokes, P.,
4 Sank, J.,
5 Moon, Wm.,
6 Wackenhut, J. E.,
7 Forstrand, A., } Equal.
8 Champion, W. B., } Equal.
9 Ferguson, G. H., } Equal.
10 Schopp, W. J. } Equal.

Strength of Materials.

1 Laherrere, R., } Equal.
2 Hatfield, A. } Equal.
3 Forstrand, R., } Equal.
4 Stokes, P., } Equal.
5 Sank, J.,
6 Schopp. W. J.,
7 Wackenhut, J. E.,
8 Champion, Wm. B.,
(9) Ferguson, G. H.

Trigonometry.

(1) Davis, W. A.,
2 Gardner, E. C., } Equal.
3 Donahue, R., } Equal.
4 Dougherty, S., } Equal.
5 Petri, A. H., } Equal.
6 Henszey, C., } Equal.
(7) Fennel, J. T.
(8) Morrison, T.

Geometry.

(1) Davis, W. A.
(2) Donahue, R.,
(3) Petri, A. H.,
4 Fennel, J. T.,
5 Gardiner, E. C.,
6 Henszey, C.,
7 Dougherty, S.,
8 Morrison, T.

Algebra.

(1) Baumgartner, W., } Equal.
(2) McDade, A. H., } Equal.
(3) Greiner, H. L., } Equal.
(6) Pladder, E. C.,
(7) Pohrt, H.,
(8) Bowen, J. M.,

(4) Paris, W. E., (9) Mauthe, J. J.,
(5) Senior, J. H., (10) Kaupp, H. A.,

(11) Cornell, E. E.,
(12) Casey, V.,
(13) Cheesman, L.,
(14) Walther, A. W.
} Took Examination for Spring term only.

REPORT OF THE NIGHT SCHOOL OF NAVAL ARCHITECTURE.—The Night School of Naval Architecture met with a fair degree of success this year. On account of the present very unsatisfactory condition of the shipbuilding industry in this country, it was not expected that a very large class would be formed at the opening of the Fall term. But eleven students were enrolled; which, considering the very limited field from which recruits are obtained, was very encouraging.

Some difficulty was at first encountered in arranging a course suitable to the diversity of mental training with which the students came equipped. But careful attention to individual needs obviated this difficulty to a considerable extent; at least so much so as to enable the students to proceed together in classes, without sacrificing the advancement of the brighter pupils to the slower progress of those less proficient. It has always been manifest that the majority of the students in this course attend for the purpose of becoming better informed concerning some particular phase of the subject; therefore an attempt has been made to gratify this desire as much as possible, and it is believed that the results have been more beneficial than if an inflexible course of study had been adhered to, which of necessity subordinates individual need to the interests of the class.

The students have been considerably hampered by a lack of suitable textbooks. This has especially been the case in considering Practical Shipbuilding. The methods of procedure described in most books on the subject differ entirely from American practice, and the information is therefore of little value to those intending to pursue their profession in this country. However, the director has endeavored to supply this deficiency by means of informal lectures and addresses.

The attendance throughout the year has been exceptionally good; and the earnest attention and honest endeavor to learn, which all the students without exception have manifested, appear to justify the efforts of the Institute to continue this course.

Mr. Frederic J. Howard has satisfactorily completed the full two years' course, and is therefore entitled to a certificate.

M. H. KEIL, *Director.*

Erratum.

(*Journal, April, 1907, p. 258.*)

ART: FRAZER—SCIENTIFIC METHODS IN THE STUDY OF HANDWRITING. Line 16. For "blue ray absorbs the red and yellow" read "red constituent absorbs the blue and yellow rays."

JOURNAL

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FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA

FOR THE PROMOTION OF THE MECHANIC ARTS

VOL. CLXIII, No. 6 82ND YEAR JUNE, 1907

Mining and Metallurgical Section.

(*Stated Meeting held Thursday, January* 31, 1907.)

Change of Structure in Iron and Steel.

WM. CAMPBELL, Ph.D., Sc.D., Columbia University.

In a former paper, which I had the honor to present to the Institute, in February, 1904, the changes which take place in the solid state were illustrated by the alloys of copper and aluminum, copper and tin, and iron and carbon. In the present paper the changes which take place in the iron-carbon series will be further considered in the light of more recent work and an attempt will be made to clear up one or two points wherein practice and theory do not always agree.

The Constitution of the Iron-Carbon Series.

The constitution and structure of iron and steel have been thoroughly worked out and with this subject will always be associated the names of Sir Wm. Roberts-Austen and J. E. Stead, in England; of F. Osmond and H. Le Chatelier, in France; of A. Mar-

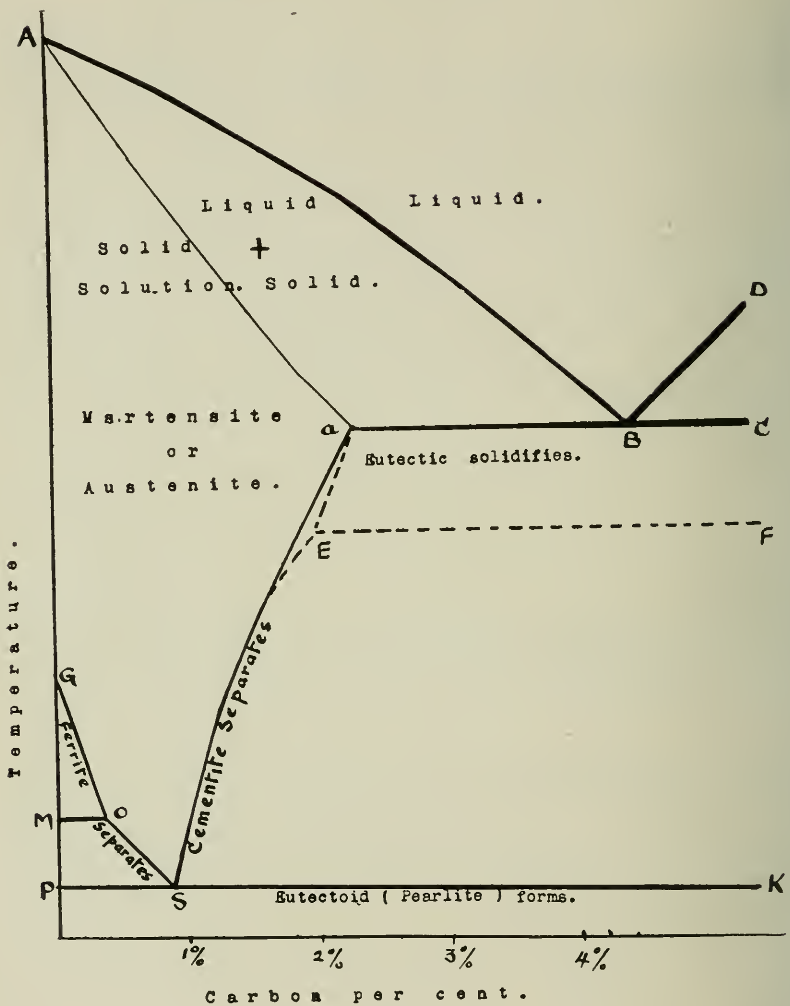
A
Liquid
Liquid.
Solid
+
Solution. Solid.
D
Martensite
or
Austenite.
a
B
C
Eutectic solidifies.
E
F
Temperature.
G
Ferrite
Cementite Separates
M
O
Separates
P
S
K
Eutectoid (Pearlite) forms.
1%
2%
3%
4%
Carbon per cent.

Fig. 25

tens and E. Heyn, in Germany; and H. M. Howe and A. Sauveur, in this country, out of a long list of workers.

In the solid state we recognize three forms of pure iron α, β, γ and whose transformation points are 760° and 900° c. The solubility of carbon in γ iron reaches a maximum of about 2% whilst in α iron it is nil.

To Roberts-Austen* we owe the first temperature-composition curve for the series, which consisted of the lines A B D, a B C, G O S E, M O and P S K. In his lectures he taught that the alloys of iron and carbon consisted of two constituents in freezing, namely, graphite and a solid containing up to 2% of carbon in solution. That at a lower temperature this solid containing carbon in solution re-arranged itself into two constituents, ferrite or pure iron and cementite or iron carbide, just as the series ice-salt changes from the liquid to the solid state on fall of temperature. Similar curves were obtained by Osmond and by Le Chatelier independently.

In 1899 was issued the Fifth Report to the Alloys Research Committee of the Institution of Mechanical Engineers. Therein is described the method of obtaining differential cooling curves. By this method, in cooling electro-iron from a white heat, evolutions of heat were found at:—

A. at 1132° C. the Ball point.
B. at 895° C. the Ar3 point of Osmond.
C. at 766° C. the Ar2 point of Osmond.

The carbon point Ar1 denoting the formation of pearlite, of course, does not exist in carbonless iron. Three lower points, however, were found, one between 550° and 600°, another between 450° and 500° and a small evolution of heat at 261° C. These lower points are due to the occlusion of hydrogen.

The curve for the iron-carbon series was corrected and brought up to date. The point A (Fig. 25) was placed just below 1600° C., a at 1.2% carbon and 1120° C., B at 4.3% carbon, G at 890° C., M at 770° C., S at 690° C. between 0.8 and 0.9% carbon. The point E at 1.8% carbon and 1000° C. formed the summit for the curve denoting the separation of cementite, which falls with increase in total carbon, till at about 4.25% carbon it meets the line S K, and ends. Above 4.25% carbon ferrite sep-

*Fourth Report to Alloys Research Committee, Pl. ii.

arates. The two lines denoting the separation of cementite and ferrite above 2% carbon were hypothetical. Just below the line a B C, a parallel line was drawn at about 1060° C. on the suggestion of H. Le Chantelier to denote the possible solidification of cementite eutectic in White Iron.

Starting with Roberts-Austen's data, Roozeboom for physical-chemical reasons added to the curve so that certain principles of solution were brought out thereby. His modification consisted essentially of adding the lines A a, a E and E F. The beginning of freezing is represented by A B D the liquidus, whilst A a B C the solidus denotes the end of freezing and below these limits the alloys are solid. When a liquid alloy cooled down to the temperature A B dendrites separated out and contained a maximum of 2 per cent. carbon in solid solution. These mixed crystals were called Martensite.* In alloys containing more than 2 per cent. carbon a groundmass, the Martensite-graphite eutectic, makes its appearance and is denoted by the horizontal line a B C. The branch B D denotes the separation of free graphite. Thus we find that from 0 to 2 per cent. carbon the alloys solidify as mixed crystals (solid solutions); from 2 to 4.3 per cent. or a to B the alloys solidify as dendrites of the solid solution (2 per cent. carbon) set in an increasing groundmass or eutectic of graphite and the solid solution; whilst above B or 4.3 per cent. carbon we have free graphite and the eutectic. Beneath the line a B C at 1130° c., therefore, we are dealing with a solid conglomerate of two phases, graphite and Martensite, with 2 per cent. of carbon in solution. The line a E indicates that the amount of carbon in the solid solution falls with the temperature and we have a further separation of graphite till at about 1000° c. and 1.8% c., the line at E meets the cementite line S E of Roberts-Austen. This means that in the normal state of equilibrium we have an abrupt transformation thus:—

Martensite (1.8 per cent. c.)+Graphite=Cementite (Fe_3C). The temperature 1000° is therefore a transition point, in other words, at this temperature only can we have three phases in equilibrium, therefore in all alloys the transformation of Martensite and graphite into cementite must occur at this temperature which is denoted by the horizontal line E F. As the tem-

*See Appendix.

perature falls below 1000° c. the solubility of carbon in solid solution Martensite decreases and we have the separation of cementite along the curve E S. This continues until we reach the line P S K at 690° when the residual Martensite, with 0.85 per cent. carbon in solution changes over into a conglomerate of ferrite and cementite, which we call pearlite. The formation of this eutectoid pearlite causes recalescence. To sum up, according to the work of Rooseboom, in slowly cooled iron or steel in equilibrium we should only find ferrite and cementite.

The publication of Rooseboom's application of the phase-rule to the iron-carbon series* raised quite a storm of criticism, mostly practice versus theory. It was argued that in most cast-irons we find ferrite, cementite and graphite; that the data on which the work was founded were wrong; that the phase-rule was not applicable outside strictly chemical lines and so forth. In the first place, most cast-irons are not pure alloys of carbon and iron. In the second, they are very seldom in equilibrium. The reaction between Martensite and graphite to form cementite would naturally be extremely slow and hence in ordinarily cooled cast-iron we should expect to find graphite by lag. It was pointed out that the reverse, cementite changing to graphite and Martensite, occurred quite readily in the manufacture of malleable castings. On the other hand rapid cooling tends to produce much cementite, while slow cooling yields much graphite.

In regard to the accuracy of the data, Carpenter and Keeling† ran a series of cooling curves for 38 alloys of carbon and iron as pure as possible and their results confirm the accuracy of Rooseboom's diagram, allowing for the differences in their determinations. For example, their freezing point for pure iron begins at 1505° c. For the eutectic alloy with 4.3 per cent. carbon at 1139° c. The line a B C rises slightly from about 1110° c. at 2 per cent. carbon to 1122° c. at 2.25 per cent. carbon, to 1139° c. at 2.75 per cent. carbon. The line P S K rises slightly also from about 690° c. with 0.12 per cent. carbon to 700° c. with 0.9 per cent. carbon, to about 710° c. with 2 per cent. carbon. G occurs about 900° c. and M about 760° c. Hence we may judge that the data were accurate.

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*Journal Iron and Steel Inst., 1900, ii. p. 311.

† National Physical Laboratory. Collected researches, i, pp. 227-244.

PLATE I. Figs. 1-6

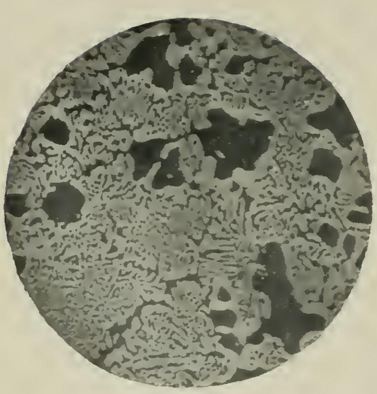

Fig. 1

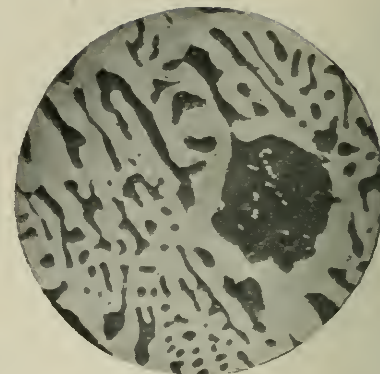

Fig. 2

Fig. 3

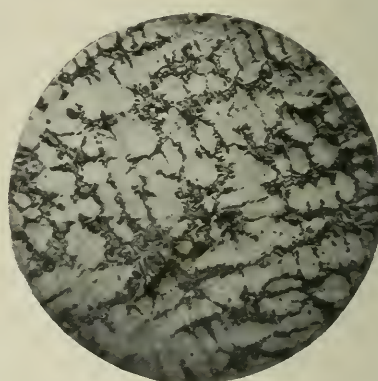

Fig. 4

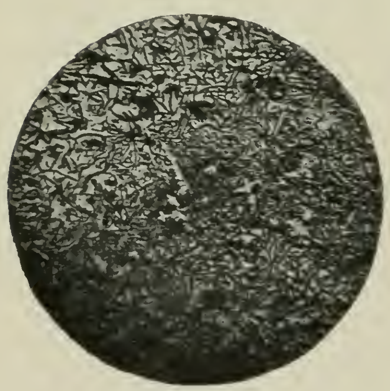

Fig. 5

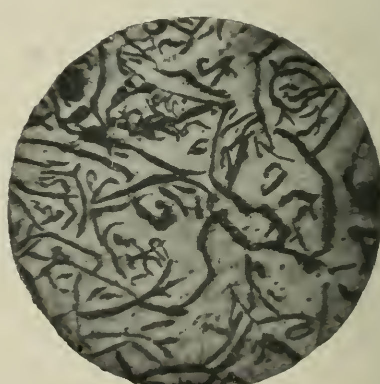

Fig. 6

Whilst Rooseboom's interpretation might readily be accepted for gray cast-irons, when we consider the structure of white cast-irons (shown in figs. 1, 2 and 3) we see that the groundmass or eutectic consists of primary cementite and the solid solution Martensite which afterwards transformed into pearlite. Were graphite a primary product and cementite a secondary one, slow cooling ought to promote the occurrence of the latter, rapid cooling yielding the former. It is a well-known fact that slow cooling promotes the formation of graphite and rapid cooling or chilling gives us cementite. The presence of silicon usually emphasizes this effect.

It seems to make the subject clearer, if we consider the two classes of cast-iron separately.

White Cast Irons. Alloys of Martensite and cementite. The line A B denotes the freezing of crystals or dendrites of Martensite holding a maximum of 2 per cent. carbon in solid solution as cementite; the line B D denotes the freezing of crystals or plates of cementite, whilst the line a B c shows the solidification of the groundmass or eutectic of Martensite and cementite. Thus up to 2 per cent. carbon the alloys form a series of solid solutions or mixed crystals, Martensite. Between a and B or from 2 to about 4.3 per cent. they consist of dendrites of Martensite surrounded by an increasing matrix of Martensite and cementite, the eutectic. Above B or 4.3 per cent. they consist of increasing amounts of cementite plates set in the same eutectic or groundmass. Fig. 1 magnified 60. is a section of washed metal containing 3.75 per cent. carbon. $Si = 0.03 : P = 0.012 : S = 0.020$. It consists of a few dark etching grains of Martensite set in a groundmass which is a mixture of dark-etching Martensite and bright cementite and is the eutectic. Fig. 2 shows a portion of the same under 260 diameters. The alloys occurring on the right of B are illustrated in fig. 3, which is a section of speigeleisen very slowly cooled, magnified 50. It consists of plates of cementite (here a carbide of iron and manganese) set in the eutectic of Martensite and cementite.

With fall of temperature below a B c, say 1125° c., the Martensite becomes supersaturated with cementite, being no longer able to hold 2 per cent. of carbon in solution. The cementite therefore separates out along the line a S which denotes the composition of the Martensite with fall of temperature till at 700° c.

or the temperature P S K, the residue contains 0.85 per cent C. and splits up into a mixture of ferrite and cementite or the eutectoid pearlite. Hence the final products will be cementite and pearlite, which are the constituents of figs. 1, 2 and 3, the pearlite appearing black, the cementite white. We have, therefore, three generations of cementite (a) the constituent of the eutectic which solidified at 1135° c., (b) the excess which separated on the line a S, (c) the constituent of the eutectoid pearlite.

Gray Cast-Irons. Alloys of Martensite and graphite. The line A B denotes the beginning of the freezing of dendrites of Martensite: the line B D the separation of flakes of graphite, whilst a B c shows the solidification of the groundmass or eutectic of Martensite and graphite at 1135°. Thus we have replaced the cementite of our white irons by graphite. There is one other great difference, however. The Martensite which separates out does not have a constant amount of carbon in solid solution. In other words the point a can vary from 2 to 0 per cent. carbon. As the temperature falls the Martensite (0—2 per cent. C.) rearranges itself into ferrite and pearlite or cementite and pearlite or pearlite alone according as the percentage of dissolved carbon was less than, greater than or equal to 0.85 per cent., following the curves G O S and S a. If we follow the Rooseboom diagram for gray-irons with say 2 per cent. combined carbon at a then we have the reaction at E to form cementite, which, of course, is incomplete. When a moves to the left, as it does with increase in silicon and from other causes, the phase-rule still requires that there should be the reaction:—Martensite (up to 2 per cent. carbon) + graphite = cementite—in order that we may only have two phases. In general this would tend to take place wherever the curve denoting the solubility of graphite in Martensite cuts the line denoting the separation of cementite.

Many observers find that cementite forms in some gray iron right from the solidification point 1135° c., which would mean the raising of E F till it coincided with a B c.

The structure of the series is well shown in Fig. 4 magnified 50. dia's. a piece of cast-iron with 2.9% C: 1.44% Si: 0.23% Mn very slightly etched. Light dendrites of Martensite a seen set in a groundmass which is the eutectic of Martensite and graphite. Fig. 5 × 35 diameters shows the eutectic alloy of Martensite and

graphite, a structure of common occurrence in gray pig-iron. Fig. 6 shows the same under the higher magnification of 120 dias. and the coarsest part of the specimen. As before the Martensite on cooling down rearranged itself by separating out ferrite or cementite and recalesced at 700° c. forming pearlite.

All irons between white and gray consist of grains of gray surrounded by a network of white, the gray apparently freezing a little ahead of the white.

The explanation that the cause of the difference between white and gray iron is silicon, does not always hold good. Carpenter and Keeling's alloys show with about 0.16% Si, up to 3.0% carbon, it was all combined, but an alloy with 0.06% Si yielded 2.14% graphite out of 3.87% total carbon. In Wüst's works* up to about 3 per cent. carbon there was only a little graphite, whilst one alloy with 0.009% Si gave 2.33% graphite with 3.76% total carbon and another with .011% Si gave 3.31% graphite out of a total carbon of 4.82%. In these exceptional cases silicon can hardly be the cause of the graphite.

Stansfield in a paper on the Present Position of the Solution Theory of Carburized Iron† comes to the conclusion that graphite does not combine with iron on slow cooling to 1050° C. and that the 2% of carbon which the iron at first holds in solid solution is rejected as graphite and not as cementite, if the metal is cooled sufficiently slowly. Instead of the line a E denoting the further separation of graphite and cutting the cementite line S E at E, a line a S′ is drawn to the left of and parallel to E S, so as to cut G O. This new line denotes the solubility of graphite in Martensite, which is therefore much less than that of cementite in Martensite. That graphite is not formed in steel he concludes, is due partly to the absence of nuclei of graphite on which further deposits might take place, partly to the length of time required for the separation of graphite, and partly to the mechanical pressure which must oppose the formation of bulky graphite in steel. The Phase Rule demands that in equilibrium there be but two constituents present. Graphite being the more stable, these two constituents must be ferrite and graphite.

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*Metallurgie, ii, p. 1.

† Journal of the Iron and Steel Institute, 1900. II 317

THE STRUCTURE AND TREATMENT OF STEEL.

Wrought Iron and Steel. When we pass from wrought iron, through mild steel, low carbon, medium and high carbon steels to those with a maximum of 2 per cent. of carbon, we embrace all that part of the curve which lies on the left of a or 2% carbon. Up to 0.85% carbon we have ferrite or pure iron and the eutectoid pearlite in increasing amounts. From 0.85 to 2% carbon we have cementite Fe_3C and the eutectoid pearlite in decreasing amounts. Fig. 7 × 90 dias is a longitudinal section of a piece of wrought iron bar which consists of ferrite and long threads of slag. The ferrite occurs in the form of polygonal grains which can be seen in fig. 8 × 260, a piece of wrought iron pipe. The slag is seen to be composite with lighter grains set in a darker groundmass. When wrought iron is strained beyond its elastic limit slip-lines are set up as in a pure metal. Fig. 9 × 80 shows several systems of parallel slip-lines in a piece of wrought iron with an extremely coarse grain. The section is perpendicular to the rolling and the round globules are cross sections of slag. Where the strain is extreme, the slag breaks up as is shown in fig. 7, which is a vertical section through a test-piece at the point of rupture. The slag has broken up into fragments between which the plastic ferrite has flowed in.

The difference between wrought iron and steel of very low carbon is mainly the absence of slag. Fig. 10 × 110 dias. shows some steel with 0.035% carbon slowly cooled from 1100° c.: it is composed of irregular grains of ferrite, with a few black dots of pearlite containing 0.85% carbon. Its physical properties are:*

	Elastic Load	Max. Load	Elong. 8"	Red. of area
As rolled	23,000	44,000	30%	68%
Annealed at 700° 3 hours . . .	26,000	41,500	33%	67%
Heated to 820°, quenched in water	34,000	56,000	9%	77%

Campbell gives an elastic limit of 27,000 lbs. per sq. in. and a maximum load of 46,000 for open-hearth steel running c. .04 Mn .04. Annealing such material for a long time at temperatures

*See Mathews J. I. and S. Inst., 1902, I.

below 750° c. causes a rapid growth of grain and the crystals become quite coarse. Reheating to just about 900° c., i.e., G in fig. A, causes refining.

An increase in carbon causes an increase in the pearlite, with an increase in strength and a decrease in ductility. Fig. 11 × 250 shows a steel with 0.10% carbon. It consists of small grains of ferrite with a few black patches which are pearlite with 0.85% carbon. Heating for a long time just below 700° causes such pearlite to segregate and split up. The ferrite is absorbed by the surrounding grains, whilst the cementite is left as islands in the midst of the ferrite. A long heating below about 750° c. also causes a coarsening of grain, whilst heating to just below 900° (G O) causes refining. Above this, the higher the temperature the coarser the grain till we reach A a where burning occurs. The coarsening of grain is very rapid above 1300° c.

A rivet steel* with C 0.10 Mn 0.40 P .011 S .01 has:—

	Tensile S.	Elastic load	Elong. 8″	Red. of area
As rolled	55,000	37,500	33%	62%
Annealed	50,500	31,000	35%	68%

Fig. 12 × 260 dias. show some steel containing 0.16% carbon which ought to give an elastic limit of about 45—50,000 lbs. per sq. in., and 65,000 maximum load with 21% elongation in 8 inches and 60% reduction of area. It is not cast steel, however, but is a photo from an area in some so-called puddled iron. The tensile tests showed up abnormally and the microscope revealed the presence of numerous areas of steel. The material is "piled" iron, made by reheating a mixture of scrap steel and wrought iron to a welding heat and rolling them out. The dark rolling lines containing slag are seen in fig. 12.

The following figures are taken from Campbell*:—

Wrought iron plate.

Elastic limit 31,000 lbs., Tensile S. 50,000.

Elongation in 8″ 15—17%. Red. of area, 22—24%.

*Manuf. and Props. of Iron and Steel, 1907, p. 248, p. 91.

PLATE II. Figs. 7-12

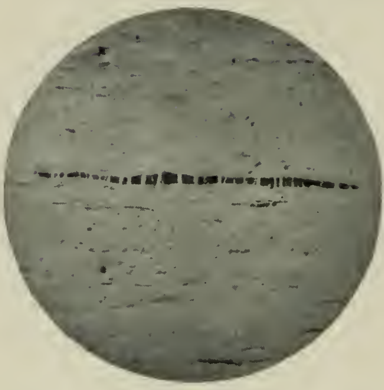


Fig 7

Fig. 8

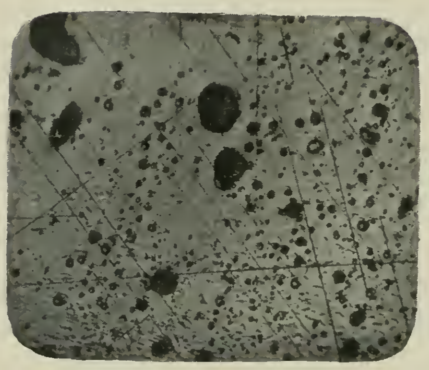


Fig. 9

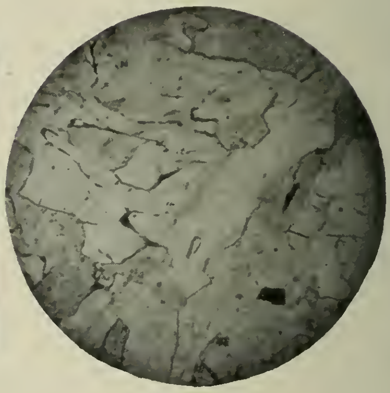


Fig. 10

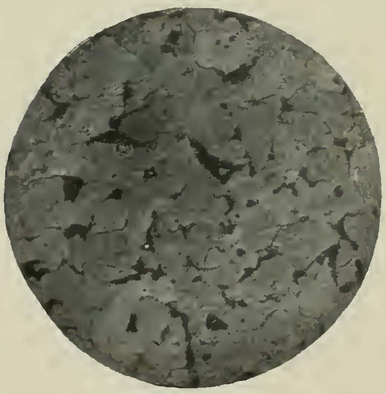


Fig. 11

Fig. 12

Chain. variations in specimens.

Tensile strength	47,500 to	70,000
Elongation 8 inch	6½% to	32½%
Red. of area	7½% to	60%
Slag	$\frac{2}{10}$ to	2¼%
Carbon	.015 to	.5
Phosphorus	.065 to	.317
Silicon	.028 to	.321

Such figures show that we may expect any results from wrought iron manufactured from steel scrap.

At about .45% carbon the amount of ferrite equals that of the pearlite in slowly cooled material. When, however, the steel has been cooled comparatively rapidly, as for instance in air, there is much more pearlite than ferrite. In other words, the pearlite contains less than .85% c. or is still holding ferrite in solution. Fig. 13 × 260 dias. shows some steel containing 0.53% carbon annealed.

In a former paper* the heat treatment of a steel running C = .0.5% Mn 1.0% was discussed.

	Elastic Limit	Max. Load	Elong. 8″	Red. area
As rolled	70,500	113,500	14	46½
Heated to 720°	63,700	102,300	17½	54½

The effect of reheating to the critical point is to reduce the strength some 10%, but this also increases the ductility. Overheating occurs about 1250° c., while refining occurs at about 720° c., midway between Ac_1 and $Ac_{2\text{-}3}$.

As we approach 0.85% c. the ferrite steadily diminishes. Fig. 14 × 260 dias. shows a steel containing C = .72 Mn .34 cooled slowly from 1050° c. The patches of ferrite are now but few and isolated. A similar steel with C = .72 Mn .22 gave

	Maximum Load	Elong. 2″	Red. of area
As rolled	118,000	16%	28
Heated to 720°	88,000	23%	48
Heated to 800°	92,000	18%	32

*Change of Structure. J. Frank. Inst., Sept., 1904.

At 0.85% carbon the steel consists of pearlite only, has one critical point S at 700° c. When we increase the carbon above this point, the excess separates out as cementite on the line a S, thus reducing the residual Martensite to 0.85% c. which recalesces at 700° c. with the production of pearlite as before. Fig. 15 × 260 dias. shows a piece of steel with 1.54% carbon 0.3% Mn. slowly cooled from 1050° c. Bright, hard veins of cementite surround the pearlite grains, whose pearly appearance shows up well, due to the slow cooling.

The effect of heat treatment on tool steels is of great importance. The following tables and curves give a summary of the results obtained on a series of 6 crucible steels 5-16 in. square running an average of 0.2% Mn. 0.01% P. 0.01% S and .2% Si. after heating to temperatures varying from 650 to 1200° c. and slowly cooling.

On examining the curves we find that the maximum loads show a great falling off till we reach the 760° c. heat, beyond which they remain fairly constant until at 1070° c. heat where extreme overheating comes in. Steel 5 shows a curious regain of strength from the 760° c. to the 855° c. heat beyond which it is constant. The elongations show a maximum for steels 6 to 3 with heat 760° c. and for steels 2 and 1 at the 800° c. heat. The reductions of area show maximum at the 715° c. heat for steels 6 and 5, at the 760° c. heat for steels 4, 3 and 2, at the 800° c. heat for bar 1. The fractures of the test-pieces showed that for the two lower carbon steels 0.7% and 1.04% overheating occurred at so low a temperature as 800° c., but with the others, higher in carbon, the temperature was above 1000° c. before extreme overheating occurred. The steel with 1.61 per cent. carbon remains the strongest to the 800° c. heat, but at the 855° heat the bar with 1.04 per cent. carbon has the greatest strength, which it maintains. Note how the 800° heat has equalized the strengths.

On examining the microstructure we find that heating to temperatures below the critical point causes a breaking down of the veins of cementite which tend to assume a globular form (e. g., change from fig. 15 to 16) and a change in the character of the pearlite. The size of grain of the pearlite does not change until the critical point has been passed. Above the critical point the higher the temperature the coarser the grain of the pearlite and the more the segregation of the cementite into globules until at

PLATE III. Figs. 13-18

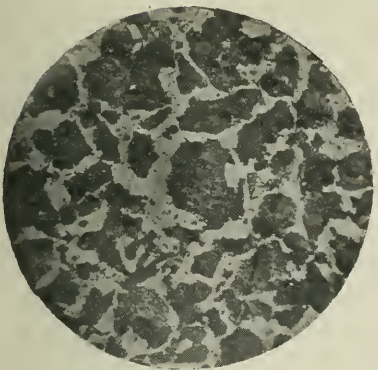


Fig. 13

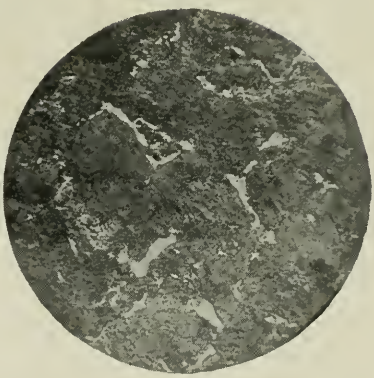


Fig. 14

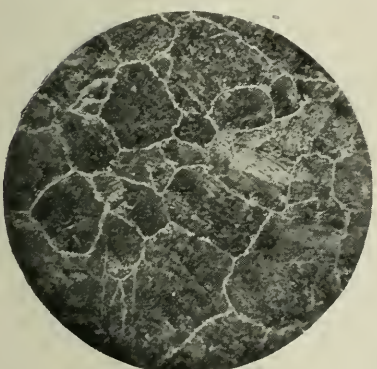


Fig. 15

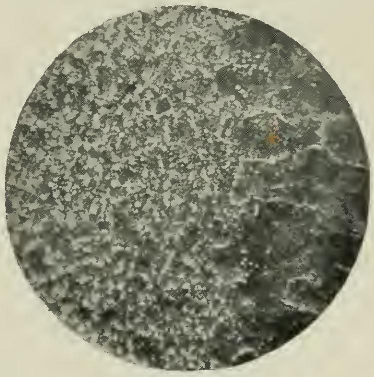


Fig. 16

Fig. 17

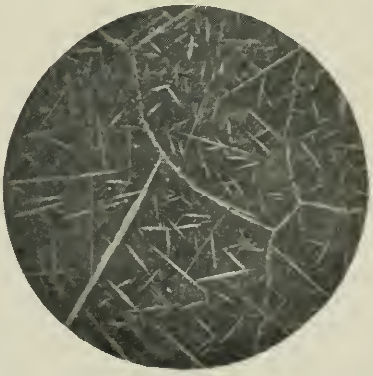


Fig. 18

above 1000° c. we find the cementite breaking down into ferrite and graphite. Fig. 16 × 260 dias. shows the steel containing 2.04% carbon heated to 950° c. The cementite has drawn together in globules, whilst on the right of the figure decarbonization of the outside of the specimen is shown by the pearlite alone. Fig. 17 × 260 dias. shows the steel containing 1.61% carbon after heating to 1070° c. We have a groundmass of coarse pearlite with a few thin veins of cementite. Most of the cementite, however, has decomposed, forming the black globules of graphite. On heating to a temperature of 1200, however, all of the cementite is taken into solution and separates out on cooling down again. Fig. 18 × 60 dias. shows the steel containing 1.72% carbon heated to 1200° c. and slowly cooled. We have extremely coarse grains of dark etching pearlite surrounded by white veins of cementite and cut by numerous needles of the same set in several parallel directions. In the case of very high carbon steels heats above 1200° c. for any time cause a melting, the carbon segregates and we have white cast-iron produced between the grains. Fig. 19 × 260 shows a steel with 2.04% carbon heated to just above 1200° c. and slowly cooled. It consists of grains of overheated steel like fig. 18 set in a groundmass of white cast-iron. Thus we judge that the normal eutectic of iron and carbon is the cementite one and that in the absence of silicon graphite is the product of decomposition of cementite.

Table 1. Bars as Received.

Bar No.	Elastic Limit Lbs. per	Maximum Load square inch	Reduction of Area %	Elongation in 2″ %	Carbon %
1a	101,800	144,600	3.53	4 5	2.04
2a	91,000	146,500	6.5	6.0	1.94
3a	98,700	152,800	5 25	6.5	1.72
4a	105,200	162,200	8.17	7.0	1.61
5a	75,800	140,600	22.7	13.5	1.04
6a	65,300	117,400	27.3	17.0	0.70

Table 2. Bars as Received.

Bar No.	Elastic Limit Lbs. per	Maximum Load square inch	Reduction of Area %	Elongation in 2″ %	Carbon %
1^x	104,200	144,000	3.04	4.0	2.04
2^x	91,500	146,300	6.0	6.5	1.94
3^x	97,500	154,000	8.68	8.0	1.72
4^x	105,200	153,200	9.14	6.0	1.61
5^x	75,800	141,600	21.8	12.0	1.04
6^x	64,200	116,600	27.0	17.0	0.70

Tables 3, 4 and 5

Treatment	Bar No.	Elastic Limit	Maximum Load	Reduction of area %	Elongation in 2″ %	Carbon %
Bars heated to 650° c.	1^3	84,600	115,400	6.52	6.0	2.04
	2^3	72,600	115,200	8.92	8.0	1.94
	3^3	78,300	126,000	7.33	8.0	1.72
	4^3	85,300	128,100	8.28	——	1.61
	5^3	57,700	105,400	36.2	18.0	1.04
	6^3	53,250	95,200	33.9	23.0	0.70
Bars heated to 715° c.	1^1	83,900	114,500	6.6	7.0	2.04
	2^1	68,660	104,100	11.97	9.5	1.94
	3^1	75,700	114,100	18.78	11.5	1.72
	4^1	81,300	117,000	21.5	14.5	1.61
	5^1	55,200	97,800	41.5	22.0	1.04
	6^1	49,700	88,700	45.2	27.5	0.70
Bars heated to 760° c.	1^6	57,700	98,800	16.16	11.5	2.04
	2^6	50,500	95,000	18.8	15.0	1.94
	3^6	50,500	100,300	20.5	16.5	1.72
	4^6	52,300	98,650	34.0	20.0	1.61
	5^6	44,850	86,800	36.6	26.5	1.04
	6^6	40,200	85,600	38.75	27.0	0.70

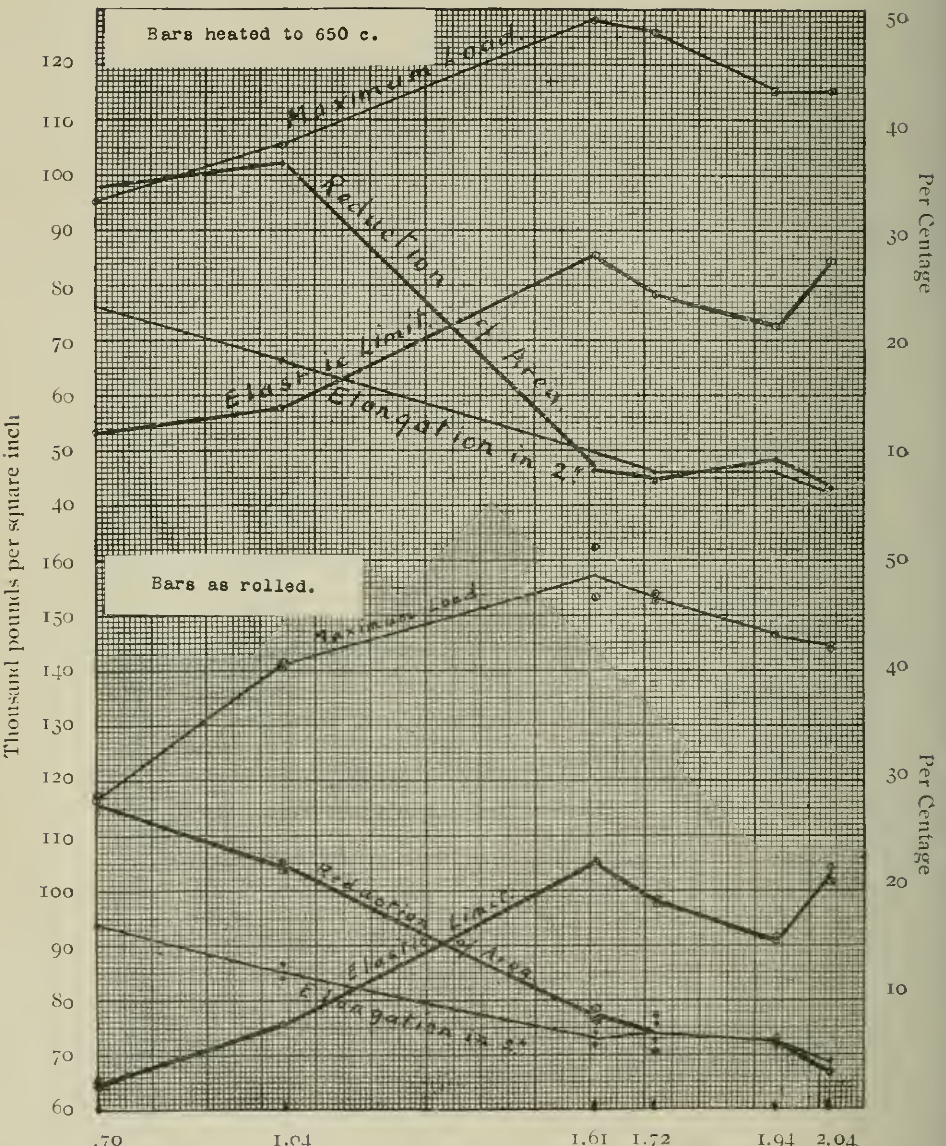
Tables 6, 7 and 8

	Bar No.	Elastic Limit	Maximum Load	Reduction of area %	Elongation in 2″ %	Carbon %
Bars heated to 800° c.	1^2	57,800	95,650	19.6	12.5	2·04
	2^2	51,000	92,000	15.0	17.0	1.94
	3^2	48,750	98,000	10.26	10.0	1.72
	4^2	53,350	97,700	19 1	18.5	1.61
	5^2	46,600	96,600	21.0	19 0	1.04
	6^2	42,150	94,300	20.9	19.0	0.70
Bars heated to 855° c.	1^4	55,500	93,800	13.2	12.0	2.04
	2^4	49,450	89,200	12.15	12.5	1.94
	3^4	47,900	94,000	12.0	13.5	1.72
	4^4	51,350	95,000	14.24	15.0	1.61
	5^4	47,200	111,800	11.3	13.0	1.04
	6^4	42,100	91,350	20.75	18.5	0.70
Bars heated to 905° c.	1^0	55,350	95,250	12.56	11.5	2.04
	2^0	49,800	95,350	9 48	7 0	1.94
	3^0	48,600	94,350	9 65	11.0	1.72
	4^0	51,350	97,350	9.4	11.5	1.61
	5^0	50,600	115,900	8.78	13 0	1.04
	6^0	41,400	90,300	21 8	18 0	0.70

Tables 9, 10 and 11

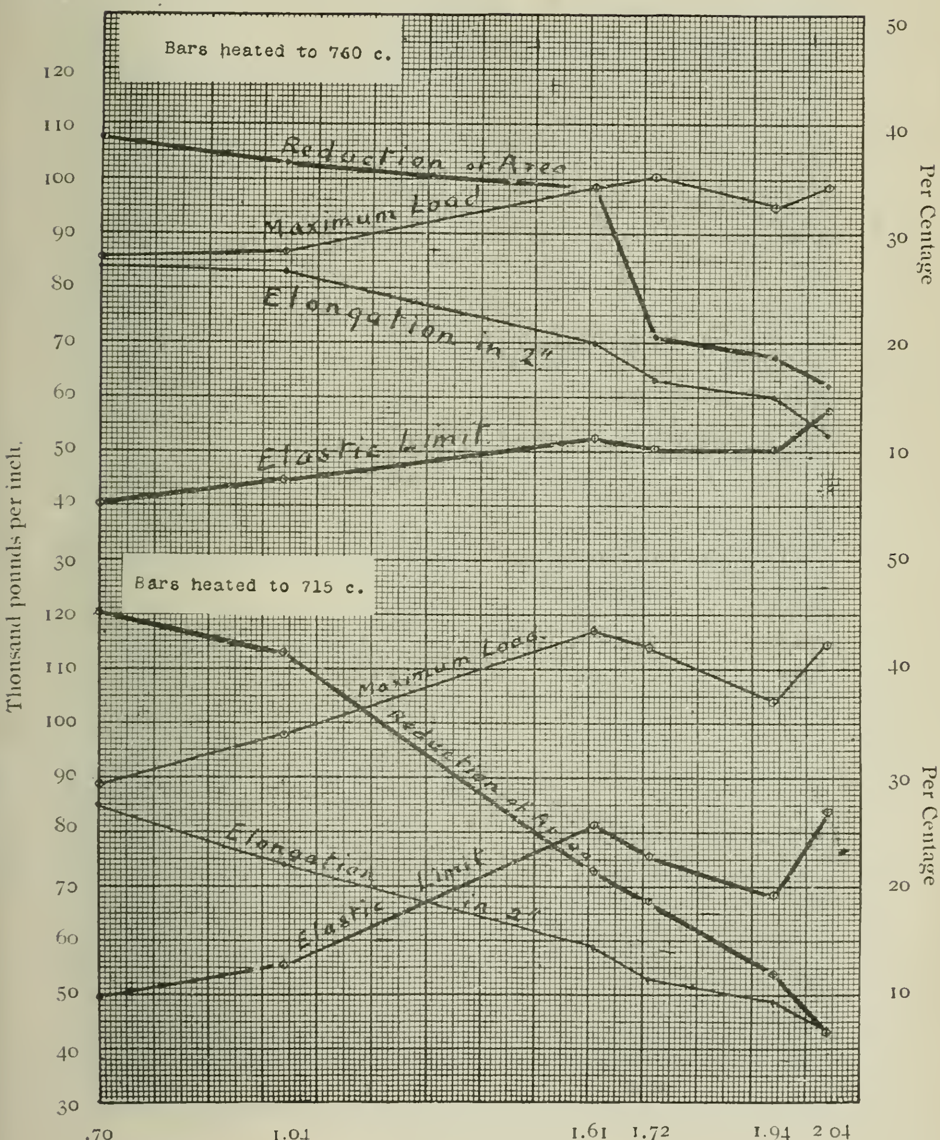
	Bar No.	Elastic Limit	Maximum Load	Reduction of area %	Elongation in 2″ %	Carbon %
Bars heated to 950° c.	1^5	49,350	95,200	5.8	6.0	2.04
	2^5	41,750	91,800	12.0	9.5	1.94
	3^5	45,200	95,000	6.33	7.5	1.72
	4^5	48,500	96,350	6.78	7.5	1.61
	5^5	46,800	111,500	10.92	10.5	1.04
	6^5	39,700	90,500	20.5	16.5	0.70
Bars heated to 1070° c.	1^z	49,600	99,000	2.72	4.5	2.04
	2^z	47,000	97,000	7.6	8.5	1.94
	3^z	43,100	92,350	4.31	6.0	1.72
	4^z	51,400	94,400	2.57	3.5	1.61
	5^z	56,500	106,100	10.58	11.0	1.04
	5^z	57,350	89,500	17.94	18.0	0.70
Bars heated to 1200° c.	1^x	56,000	57,400	0.4	1.0	2.04
	2^x	———	61,350	1.41	2.0	1.94
	3^x	50,600	65,300	1.02	2.0	1.72
	4^x	———	69,800	1.86	3.0	1.61
	5^x	89,600	112,600	10.7	11.5	1.04
	6^x	58,500	90 000	16.84	16.0	0.70

Curves 1 and 2



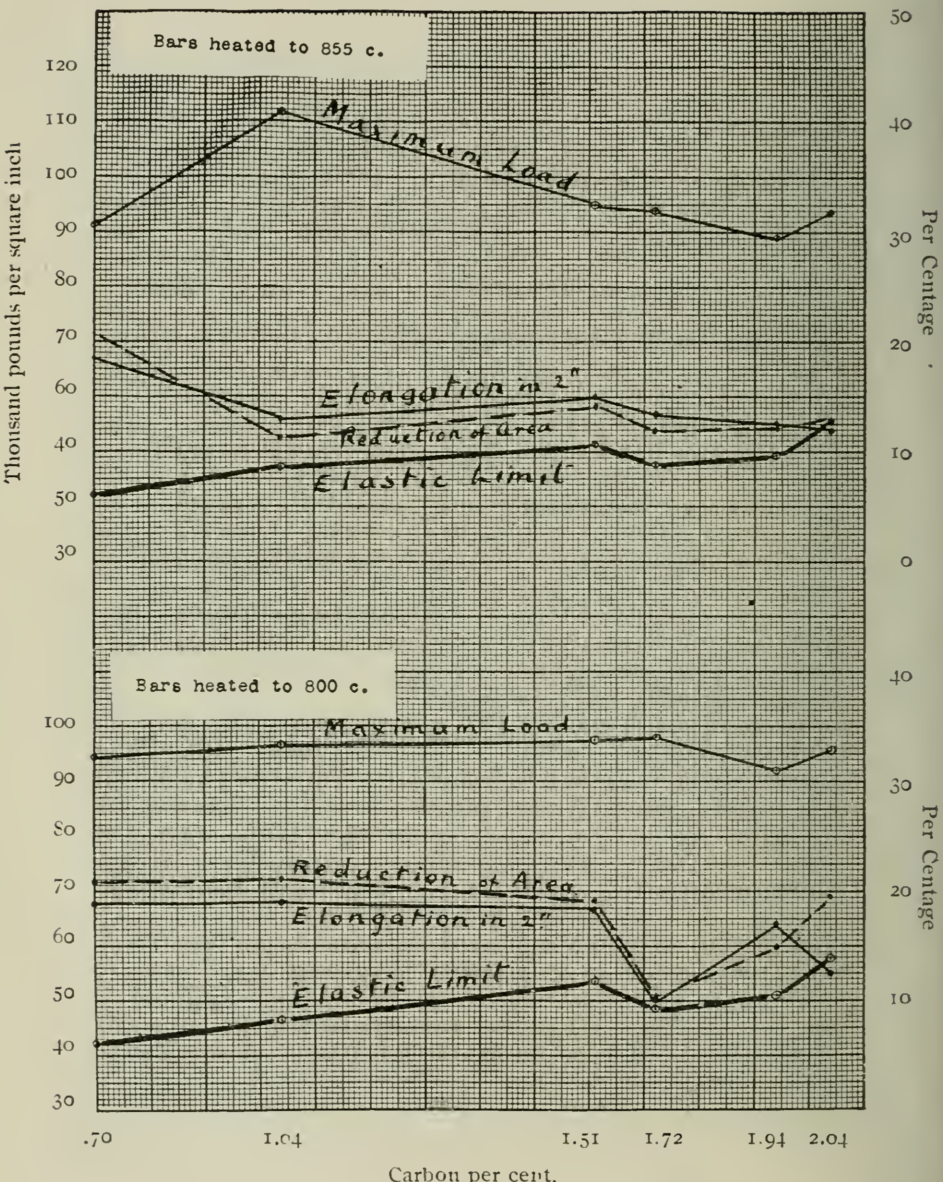
Carbon per cent.

Curves 3 and 4

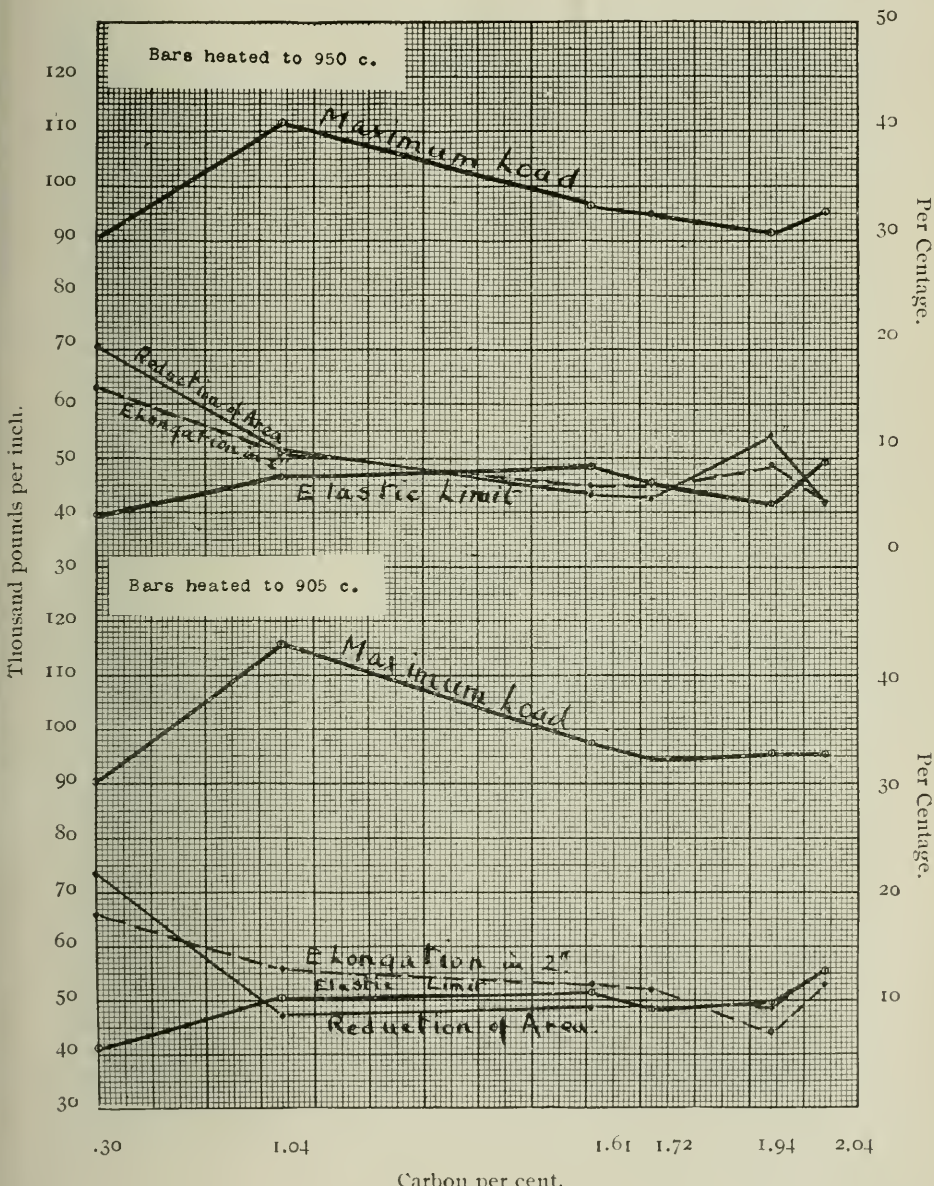


Carbon per cent.

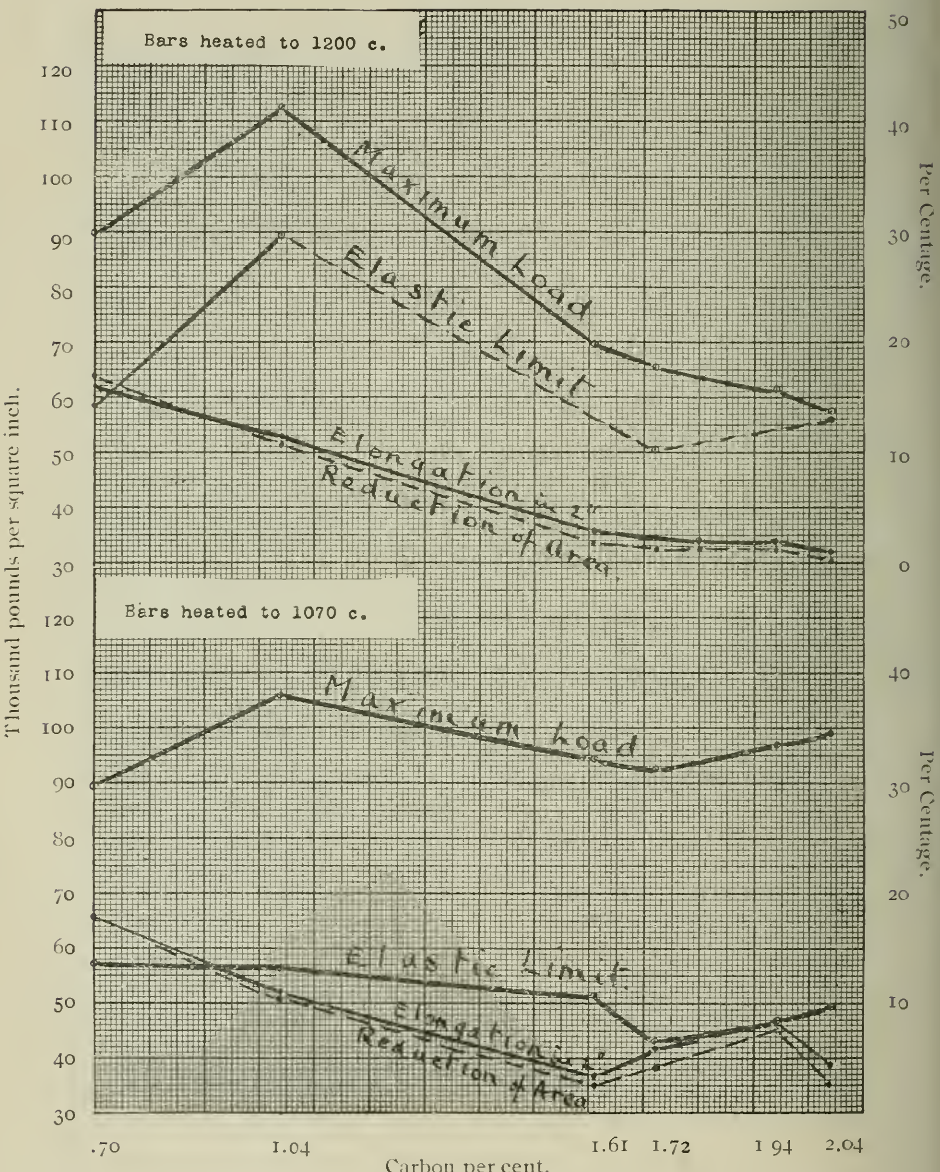
Curves 5 and 6



Curves 7 and 8



Curves 9 and 10



Heat Treatment of Cast-Iron.

In the manufacture of malleable castings from white cast-iron on passing 700° c. the pearlite changes over into Martensite: at a little above 1000° c. the cementite breaks down into ferrite and graphite. Is silicon essential to the process? Most people think so. Tiemann* made some silicon free cast-iron with total carbon 4.5, graphite .255. This material was heated to all temperatures up to the melting point without causing the cementite to decompose. On the other hand, Wüst, with a white iron of 3.8% carbon and not more than 0.008% Si on heating for 50 hrs. at 980° C. in a vacuum and slowly cooling produced a product consisting entirely of pearlite ferrite and temper carbon, the whole of the cementite having decomposed.

An experiment was performed with some pieces of washed metal (C = 3.75 Si 0.03) which were heated to about 1050° c. in an oxidizing atmosphere. Fig. 20 shows a section near the surface of one of the pieces. In the center we have the original white cast-iron showing no trace of graphite, whilst around it lies an area of cementite and pearlite running about 1.5% carbon, due to decarbonization. No sign of any graphite was seen. One specimen, however, did show graphite, seen in fig. 21. On the right lies the original white cast-iron, whilst on the left we have material corresponding to about 1.5% carbon steel, well mixed with graphite flakes. Thus in one specimen we found the decomposition of cementite into graphite had occurred, whilst in all the others it failed to appear. This shows that the reaction is not constant under the conditions used, and that sometimes graphite appears, in others the cementite remains undecomposed.

Cementite in solution in the Martensite is certainly stable at these temperatures as shown by fig. 18. The process of making Blister Steel also shows this. Wrought iron is heated to a bright red or white heat in contact with carbon. The iron is in the γ range and Martensite is formed by diffusion. Fig. 22 × 60 dias. shows some half cemented steel which is composed of bright ferrite and darker, coarse pearlite. Fig. 23 × 260 shows the same: the pearlite is seen to be extremely coarsely laminated with a band or border of cementite due to segregation in slow cooling. Fig. 24 × 260 shows some fully cemented bar. The black

*Metallographist, iv 303.

PLATE IV. Figs. 19-24.

Fig. 19

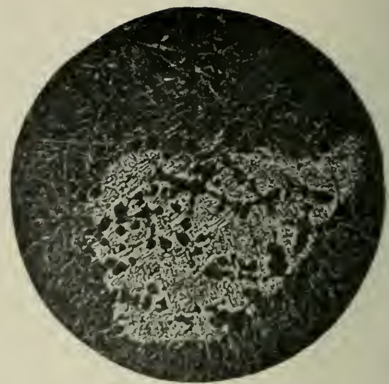


Fig. 20

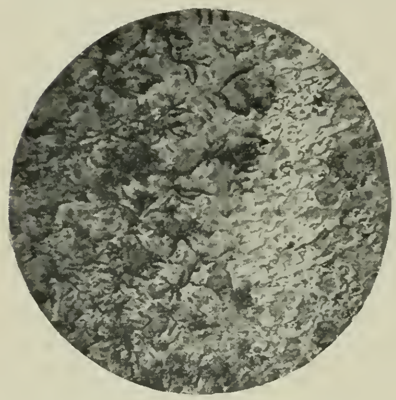


Fig 21

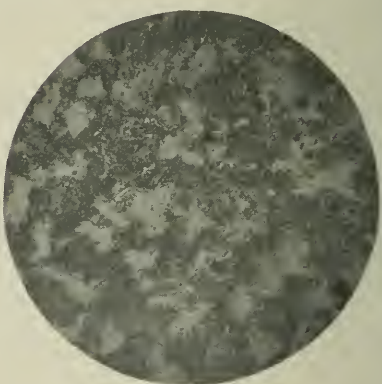


Fig. 22

Fig. 23

Fig. 24

streaks are the original slag of the wrought iron. Slow cooling has produced a coarse pearlite in which are set thick veins and patches of cementite. Thus we can produce a cement steel up to 2 per cent.+of carbon without forming graphite, but reheating the same would cause the formation of graphite due to the breaking down of cementite around 1050° c.

SUMMARY.

From our present knowledge we must judge the cementite-Martensite series to be the unstable one. Absence of silicon and rapid cooling tend to cause white cast-iron. When high carbon steels are heated to their melting point and slowly cooled, white cast-iron is formed. Pure cast-irons with a comparatively small amount (2—3%) of carbon tend to be white.

Gray cast-irons are the Martensite-graphite series which occur with much silicon and slow-cooling. The presence of much carbon (3%+) tends to produce a gray iron.

Graphite is formed due to the decomposition of cementite by reheating to temperatures around 1000° c. In steel a higher temperature (to melting) causes the solution of the cementite or formation of white cast-iron. In malleable castings the action is similar, cementite breaking down into ferrite and graphite. Too high a heat retards and even prevents this reaction.

Most cast-irons are a mixture of white and gray or cementite, Martensite and graphite, the gray forming a mesh in a network of white cast-iron which forms at a slightly lower temperature. This structure is probably due to the presence of silicon, manganese, phosphorus and sulphur in varying amounts.

The simultaneous occurrence of cementite and graphite in certain specimens of siliconless irons can not be explained satisfactorily except by assuming that we are dealing with two systems:—

(a) Ferrite and Graphite,
(b) Ferrite and Cementite,

which Benedicks calls the stable and the meta-stable systems respectively. This does away with the necessity of assuming a reaction between graphite and Martensite to form cementite in the region of 1000° c. which Rooseboom himself no longer holds.

In conclusion I must express my indebtedness to the Carnegie

Institution of Washington for a grant to carry on research on the heat treatment of iron and steel.

APPENDIX.

In the above paper the name Martensite has, for the sake of convenience, been used in its old meaning, the solid solution of carbon in iron or what is often termed mixed crystals. Now, however, the solid solution is known as austenite, and Martensite is a transition product. Recently Sauveur* has dealt with the subject and from his paper we learn that:—

Austenite is a solid solution of carbon in γ iron.
Martensite is a solid solution of carbon in β iron.
Troostite is a solid solution of carbon in α iron.

Pearlite is the iron-carbon eutectoid, in other words a mechanical mixture of ferrite and cementite. Thus austenite, Martensite, troostite and pearlite form a series. Martensite and troostite being transition products between the original solid solution and the eutectoid. Sorbite or the unsegregated form of pearlite would therefore occur between the latter and troosite.

BRITISH TRADE IN LATE YEARS.

The London *Statist* for February 9 says: "Two distinctly interesting features of the growth of our foreign trade during the last two or three years have been, first, the very large expansion in our exports to foreign countries and the relatively small increase in our exports to our colonies, and, secondly, the moderate increase in our imports of produce from foreign countries and the considerable expansion in our imports from our colonies. In three years the exports of the produce of the United Kingdom to foreign countries have expanded £74,770,000, or over 41 per cent., while the growth in our exports to our colonies has been only 9 per cent. In a period of two years and six months the expansion in the value of the exports of British produce has exceeded the expansion in our net imports by no less than £49,659,000. From whatever point of view these results are regarded no one can fail to be delighted that the trade of the country has expanded in this remarkable manner."

*Journal of the Iron and Steel Institute, 1906, IV, 493.

Mechanical and Engineering Section.

(*Stated Meeting, held Thursday, March* 15, 1906.)

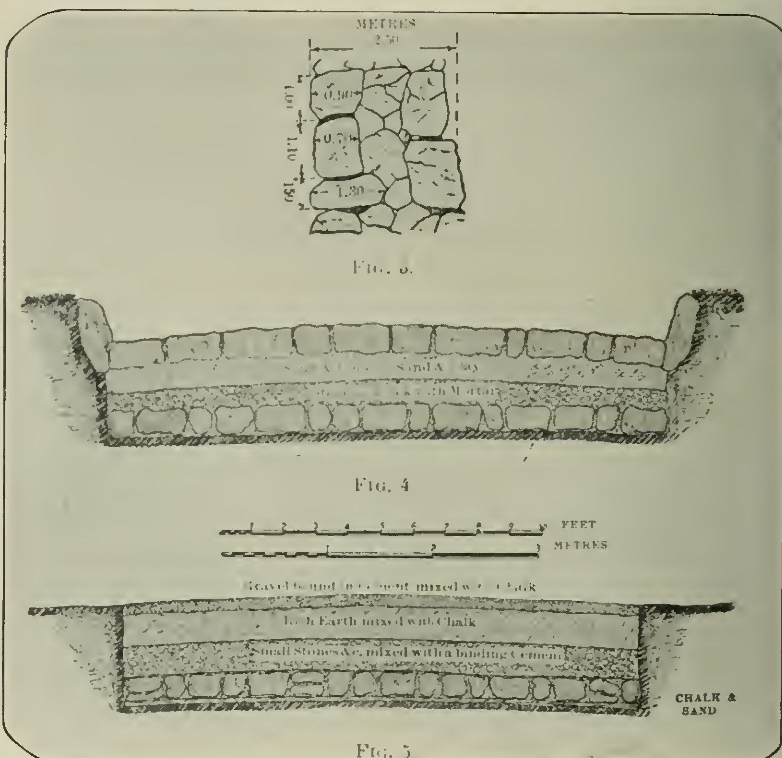
The Development of Street Pavements.

George W. Tillson, Chief Engineer Bureau of Highways, Borough of Brooklyn.

Thirty years ago there was not a mile of pavement in existence such as is considered standard at the present time—it will therefore be of interest to study the causes which led to the use of the different materials in vogue at that time and also what led to the changes that have resulted in the adoption of the materials now in use.

It is said that the remains of an old road formed of broken stone have been found near the great pyramid in Egypt; this road was undoubtedly constructed for the purpose of carrying stone across the sandy desert for use in the construction of that pyramid. As this pyramid was built about 4,000 B.C. this road is unquestionably the oldest one on record. When the Romans invaded Africa for the destruction of Carthage about 150 B.C. they found a well established road system which aided them very materially in the mobilization of their armies. The practical use of these roads evidently led them to construct others in their subsequent invasions in European countries, as wherever they went they left a large extent of well constructed roads. Pavements proper, however, were not very much in use until later times. Rome had its first pavements in the 4th and 5th centuries after the founding of the city, and the first pavements in Paris were laid in 1184, when the city already had a population of about 200,000. The Strand, London, was ordered paved by an Act of Parliament in the 14th century when its population was 100,000. When it is considered that cities at the present time containing five or ten thousand people have a considerable amount of pavements, it must seem strange that these older cities existed so long with unimproved streets. The explanation of this is that besides

their lack of civilization, there was very little traffic carried on by means of wagons—most of it being done by means of pack-horses and other beasts of burden. It is said that in the reign of Queen Elizabeth only 420 carts were allowed on the streets of London—the merchandise all being carried on pack-horses; and one hundred years later trains of pack-horses were regularly started from London to different parts of England. In 1625, in a population of 265,000, there were only twenty hackney



An Old Roman Road.

coaches in use. All traveling in France was done on horse-back until the latter part of the 16th century. In the city of Paris in 1550 there were only three carriages. The oldest pavements this generation has been able to see are those that have been disclosed by the excavation of the streets of Pompeii; the streets were narrow and the roadway was formed of large and irregu-

larly shaped stones, laid flatwise. These pavements are in a good state of preservation and are fair samples of work of that character done 2000 years ago.

As late as 1826 an engineer in London who had been investigating pavements on the Continent, wrote as follows:

"Florence, Sienna, Milan and other Italian cities have pavements with specially prepared wheel tracks. These tracks are

A Paved Street in Pompeii.

three feet in width, made of large and well laid stones. They are about four feet apart and the space between paved with smaller stones."

He also says these pavements as well as similar ones he saw in Rome are the best he has ever seen, but he adds that they are too expensive for London. When the relative importance of these cities and London at the present time are considered this state-

ment is very interesting. As a rule the early pavements were made of large and irregularly shaped stones, laid flat and with very little care. As traffic increased, however, the necessity of better streets became apparent and the character of the pavement gradually improved. The stones were selected with more care and shaped roughly so as to make a smoother surface. In Italy the development took the line of large flat stones, oblong in shape, approximately two or three feet long and twelve or eighteen inches wide. Such stones could not, however, prove satisfactory and were not long used where the traffic was heavy. Some streets in Italy are paved with such stones at the present time. The well-known cobble stone was also used in the development of pavements. It came into very general use probably on account of its availability and cheapness. As the development continued it resulted in the formation of what is known as the Belgian block. These blocks were so called because first used in Belgium, and were in shape practically cubical blocks. They make a very good and serviceable pavement, but are expensive. Following this came the oblong granite blocks such as are in use in our American cities at the present time.

The development of pavements in this country was practically the same as that in Europe, although very few of the large flat stones were used. Probably the first pavement laid in America was laid on a street in Pemaquid, on the coast of Maine, in 1626. This pavement has been unknown until recently when it was discovered by a farmer who in ploughing up his field met with an obstruction. On investigation a well defined paved street was discovered and from the best information available it was thought that this must have been laid about 1626; the material was cobble stone. Cobble stone pavements were laid in New York and Boston practically at the same time, viz: 1656. In the early days of New York the Dutch built several breweries on the road lying between Broad and Whitehall streets, which has since been called Brower street. The brewery wagons created such a dust that the wives of the good burghers made complaints and finally the roadway was paved with stones. The street was then known as the Stone street and it was visited as a curiosity by a great many people. Since that time the name has been changed to Stone street, by which it is known at the present time.

It is possible to trace the laying of pavements in the city of

New York quite completely. Cobble stones were used entirely until 1849 as the regular material, although a few wooden blocks had been laid experimentally in lower Broadway in 1835. In 1849 Broadway was paved as far north as Franklin street with what was known as Russ Blocks. These blocks were from two to three feet square and on grades were grooved in order to give better foothold for the horses. This pavement was relaid in 1868. In 1865 an experimental iron pavement was laid on Cortland street. This consisted of short cast-iron cylinders placed on end with the spaces between and the interiors of the cylinders filled with gravel. Other similar pavements to this have been laid with the spaces filled with cement concrete. As might have been expected, this payment was not satisfactory.

The so-called Belgian blocks were laid for the first time on the Bowery in 1852, and came into general use in 1859. They were supposed to be, and were, an improvement over the old cobble stone pavement. It was soon found they would not make a satisfactory pavement and in 1876 the present well known granite blocks were used. What is known as the Guidet Patent Granite Blocks had been laid a few years previously. These blocks were practically the same as the granite blocks used to-day. Quite a quantity of this pavement was laid in Brooklyn in 1869 at a cost of about $7.00 per yard on a sand base. Although the patentee claimed royalty and brought suit against the city for the use of these blocks, the final decision of the court was against him and no royalty was recovered. The blocks were very large, some of them still remaining on one of the Brooklyn streets at the present time, being five to six inches wide and from eighteen to twenty inches long.

Asphalt in an experimental way was laid near the Battery in 1871. The condition of the New York pavements was such that a general scheme for their improvement was adopted in 1889, special legislation being obtained for issuing bonds for carrying out the work. From this time dates the beginning of the present improved pavements in New York city.

Cobble stones were used very largely in cities near the coast—Brooklyn, Philadelphia and Baltimore probably having the largest quantities. According to a bulletin issued in 1899 by the United States Department of Labor, Baltimore had 5,815,610 sq. yds. of cobble stone pavement, New York City 4,213,616 sq.

yds. and Philadelphia 2,920,664 sq. yds. This amount has been reduced in Brooklyn to 78 miles or about 160,000 sq. yds. (the other boroughs in New York City having practically no cobble stone pavements), and to 61.4 miles in Philadelphia.

In 1843 a committee of engineers was appointed by your own Franklin Institute for the purpose of investigating and reporting upon the best material to be used by the City of Philadelphia. After a careful examination this committee reported in favor of three kinds of pavements: the first to consist of dressed stone blocks, laid in diagonal courses, the blocks to be 8 inches deep, 7-9 inches wide and 8-10 inches long. This pavement was estimated to cost $3 per sq. yd. On streets of the second class the pavement was to consist of two stone tramways to accommodate traffic in both directions—the spaces between the trams and curbs to be paved with cobble. This pavement was estimated to cost $1 per sq. yd. The streets of the third class were to be paved with cobble stones. The committee reported as the best shape for the cobble stone: "They would be prolate spheroid generated by an ellipse of which the major axis is double the length of the minor." This report seems to have met with the fate of most such reports, as in 1884, forty-one years after its date, ninety-three per cent. of the entire pavements in Philadelphia were cobble stone—the entire length of the pavement being 535 miles. How closely the shape recommended by the committee was followed out in other cities is illustrated by a stone the speaker once measured in a Brooklyn street, which was 3 feet 10 inches long by 11 inches wide and he never learned how deep.

Wood as a paving material seems to have been used in this country in cycles of twenty years. During the forties wood was adopted quite extensively in Philadelphia, New York and Boston. No particular attempt was made to select suitable kinds or lay it in any special manner and the result was what might have been anticipated, very unsatisfactory, and its use was soon discontinued. In the sixties the well-known Nicholson wood pavement was used to quite an extent throughout the country and for a few years gave quite satisfactory results, but the uneven decay and wear of the wood soon caused the pavement to become rough, and it lost its popularity. In the eighties the cedar block pavement craze spread throughout the growing cities in the West, and many million yards of this pavement were laid. It was

MILEAGE OF PAVEMENTS IN LEADING AMERICAN CITIES

Character of Pavement.	Brooklyn			Boston			Buffalo			Chicago		
	1890	1900	1906	1890	1900	1906	1890	1900	1906	1890	1900	1906
Asphalt	10.85	68.82	263.48	4.65	13.80	21.16	106.03	222.74	228.71	9.24	78.60	271.43
Stone Block	83.90	159.95	186.53	69.27	86.97	96.34	140.69	104.50	98.91	23.10	29.77	48.47
Cobble	289.21	236.85	78.40	5.95	1.01	0.30	. . .	. . .	. . .	. . .	. . .	.
Rubble	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	.
Brick	. . .	3.78	3.62	0.35	0.80	0.38	0.07	7.47	14.20		29.51	87.41
Macadam	2.81	78.57	99.81	204.57	280.57	337.10	3.28	3.08	11.90	227.01	363.40	490.54
Coal Tar and Concrete	. .	. . .	. . .	BITULITHIC		5.00	. . .	. . .	.	. . .	. . .	. . .
Garnolithic	. . .	. .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Slag Block	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Wood	. . .	. .	2.16	. .	. .	0.91	. . .	. . .	. . .	410.29	763.21	581.18
Miscellaneous	. . .	. . .	. . .	GRAVEL		33.57	. . .	. . .	. . .	. . .	4.88	6.54
Total	386.77	547.97	634.00	284.79	383.15	494.76	250.07	337.79	353.72	669.64	1269.37	1485.57

Character of Pavement.	New York			Philadelphia			St. Louis			Washington		
	1890	1900	1906	1890	1900	1906	1890	1900	1906	1890	1900	1906
Asphalt	16.34	162.44		43.40	254.10	379.69	3.95	11.81	41.87	51.80	129.27	*160.81
Stone Block	273.75	272.73		119.60	352.20	378.60	42.46	50.36	62.88	23.50	27.19	25.99
Cobble	3.33	1.10		375.10	69.20	61.40	. . .	. . .	. .	11.50	11.31	9.68
Rubble	. . .	. . .		115.50	43.30	. .	. . .	.	.	. . .	. . .	. .
Brick	. . .	1.10		19.80	119.50	145.71	. . .	14.23	79.82	. . .	0.4[illegible]	[illegible].92
Macadam	24.23	113.12		88.80	193.50	273.34	290.08	351.92	BIT. 20.21	8.00	34.39	77.11
Coal Tar and Concrete	. . .	. . .		. . .	. . .	. . .	. . .	. . .	. . .	38.21	14.08	
Garnolithic	. . .	. . .		. . .	12.80	12.77	. .	. . .	. . .	. . .	. . .	
Slag Block	. . .	.		. . .	5.60	9.82	. . .	. . .	. . .	. . .	. . .	. .
Wood	. . .	. . .		. . .	. . .	. .	5.76	6.89	3.33	0.30	. . .	
Miscellaneous	. . .	0.08		. . .	. . .	. . .	. . .	. . .	291.01	. . .	. . .	.
Total	317.65	550.57		762.20	1050.20	1261.33	341.75	435.21	499.12	133.31	216.64	274.51

*Includes coal tar.

TOTAL ASPHALT PAVEMENT

1890	1906
229.92	1367.15

TOTAL BRICK PAVEMENT

1890	1906
20.22	332.06

yds. and Philadelphia 2,920,664 sq. yds. This amount has been reduced in Brooklyn to 78 miles or about 160,000 sq. yds. (the

pavement craze spread throughout the growing cities in the West, and many million yards of this pavement were laid. It was

only a make-shift pavement and in a comparatively few years was not seriously considered as a paving material and not used to any great extent except in Chicago. In the present decade the use of wood has again come to the front and it is not only being seriously considered, but has been generally adopted as a suitable paving material. It must be remembered, however, that it is a very different material from what has ever been used before, as not only the best quality of wood is selected, but it is treated chemically so that it will not decay, and the length of its life will depend upon the amount of traffic it sustains. This is the theory of the promoters, and present experience seems to justify their claims. Wood has been used in the larger cities of Europe for quite a number of years and there it is generally untreated. Pine and deal wood are used as well as hard woods imported from Australia. The conditions in these cities, however, are different from those in American cities, as the traffic in London and Paris is such that the blocks wear out before they decay, so they do not require to be treated chemically.

Asphalt was first used in any great amount in Washington, when Pennsylvania avenue was paved with it in 1876. The success of this pavement was such that it gradually grew into popularity; it is probable that during 1905 a greater mileage of this pavement was laid in the larger cities than that of any other kind. The accompanying table shows the changes in the character of the pavements in the cities of Brooklyn, Boston, Buffalo, Chicago, New York, Philadelphia, St. Louis and Washington. This table shows very plainly the popularity of asphalt as a paving material and also that of brick. It is undoubtedly true that if the smaller cities, in the Middle West especially, had been used as examples, a much larger proportion of brick pavement would have been shown. A great deal of experimenting has been done in trying to secure good pavements and the best material with which to construct them. In 1874 seventy-six patents had been issued by the Government for constructing pavements of coal tar, asphalt and other bituminous material, and pavements more or less successful have been laid in this country and in Europe of wood, asphalt, coal tar, cement concrete, iron, brick, India rubber, shells, gravel, slag blocks and even glass and hay. At the present time the following pavements are considered standard: Asphalt, wood block, stone block, asphalt block, brick, and bitu-

lithic pavements. A large amount of macadam is being laid every year, but it cannot be considered a standard pavement.

Asphalt Pavements:—Asphalt pavements were first laid in the city of Paris—the first street being paved in 1854. These pavements were very popular in Paris, but were not entirely satisfactory on account of slipperiness. The European pavements were of a different character than those of this country. The former consist of asphaltic rock, which is taken from the mines, ground, then heated and transported to the street, where it is compressed by tamping and rolling so as to reproduce the origi-

Sheet Asphalt Pavement. Borough of Manhattan New York City.

nal rock as nearly as possible. The stone containing the asphalt is lime stone and for that reason the pavement is slippery.. The entire pavement must be transported from the mine to the plant and then to the street, so that the expense is comparatively large where the mines are a long distance from the streets to be paved.

The success of these European pavements, however, was such that experiments were made in this country in the sixties to reproduce if possible the European pavements, or something equivalent thereto. The original bituminous pavements were

made of coal tar, the first one probably in Brooklyn, in 1868. Washington laid a large amount of coal tar pavements, some of which are in existence to-day, having been down over thirty years. Coal tar, however, is not a stable or even material, and while some of these pavements were durable, others disintegrated in one or two years, so that coal tar as a paving material lost caste and asphalt from the Island of Trinidad was used as a cementing material. These original coal tar pavements consisted of sand and gravel bound together with coal tar.

Asphalt is a hard natural bitumen found in nature. It is quite generally scattered over the earth's surface. It is formed from petroleum oil in Nature's great distillery, requiring no one knows how long for its formation. It has been seen in California in every grade of its distillation from the crude oil to the hard asphalt.

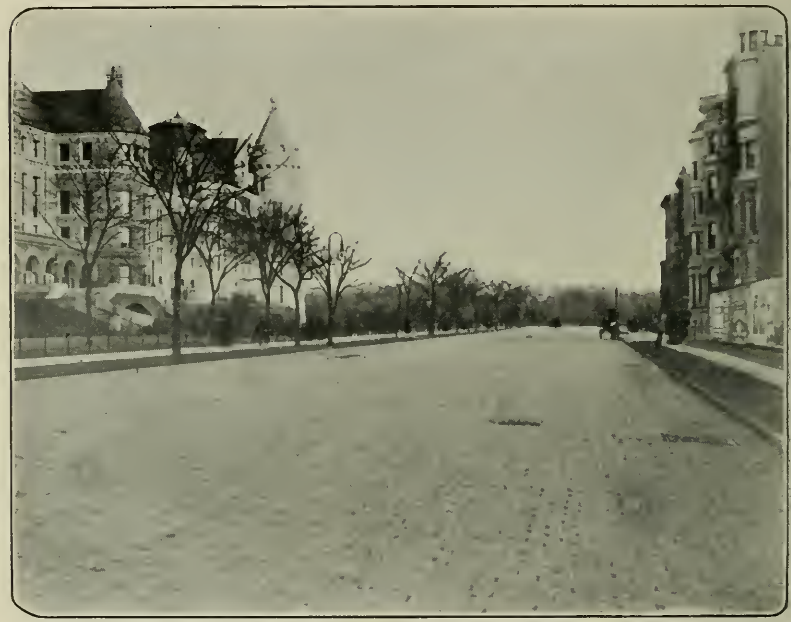
Asphalt is also produced by the artificial distillation of these California oils and when the work is carefully done the resulting product is satisfactory.

The asphalt now in use comes principally from Venezuela, Trinidad and California.

In an asphalt pavement, asphalt itself forms only from ten to twelve per cent. of the entire pavement, the remainder being sand and stone dust. In almost every locality suitable sand can be found within a reasonable distance that would make cheap pavements, so that only ten or twelve per cent. of the entire pavements would have to be brought from a mine, thereby materially reducing the expense of the pavement to such an extent that European pavements cannot compete in cheapness with those laid according to the American methods. While not a perfect pavement by any means, asphalt appears on the whole to give the best satisfaction for residence streets at the present time, and it seems bound to be a very important factor in street pavements for the future. It is comparatively noiseless, easily cleaned and its smooth surface is pleasing to the eye. One of its principal disadvantages is its slipperiness under certain conditions. If, however, the pavement is kept clean, there will not be much trouble on that account, as the pavement when wet is not as slippery as when it is simply damp. The matter on the surface of the pavement makes it slippery rather than its composition.

Asphalt Block Pavement:—Another form of asphalt pavement

is constructed from blocks. The blocks were originally 4x5x12 inches in size and laid on a gravel base. This made an expensive pavement, and the blocks have gradually been reduced in size until now they are generally laid 3x5x12 inches on concrete base with half-inch cement mortar cushion. These blocks are made with an hydraulic press under pressure of about 5000 lbs. per sq. inch. They are used principally on grades and where the traffic is supposed to be too heavy for sheet asphalt. They



Asphalt Block Pavement. Borough of Manhattan, New York City.

make a good, durable pavement when the blocks themselves are good. It is obvious that poor blocks will not make a good pavement. Great care must be used in making blocks and a thorough knowledge of their manufacture should be had by anyone attempting to make them. Specifications for blocks have never been standardized, or even made definite. They should be made of good substantial rock, and so dense that they will not absorb an appreciable amount of water, and so strong that they will not break or crumble under traffic. The stone used should be trap rock as nearly cubical in form as possible and ranging in size

from that which will pass through a $\frac{1}{4}$-inch hole to the fineness of dust and so graded as to have as few voids as possible. The asphaltic cement should be of such a character as to bind the particles of the stone together, and in amount should be about six to eight per cent. of the entire mass. Such a block should have a specific gravity of not less than 2.45, and if properly made should not absorb more than one per cent. water when immersed for twenty-four hours. Asphalt blocks must necessarily be made at a central plant and transported from the plant to the street, so

New Medina Sandstone Pavement. Borough of Brooklyn. New York City.

that they are somewhat more expensive than sheet asphalt. The pavement has increased in popularity from year to year and a great amount is constantly being laid.

Stone Block Pavement:—Stone block pavements of to-day are laid practically of granite blocks, but in Rochester, Buffalo and Cleveland the sand stone from the Medina quarries, in the western part of New York State, is used and giving good satisfaction. The granite blocks are generally from $3\frac{1}{2}$ to $4\frac{1}{2}$ inches wide, 7 to 8 inches deep by 12 inches long; the Medina blocks

varying somewhat from this. The standard pavement is laid on a concrete base. the joints being filled with some impervious material. The custom in the vicinity of New York is to fill the joints with coarse gravel, the interstices of which are filled with coal tar. In some vicinities, however, cement grout is used for the filling both for granite and Medina sand stone. Tar and gravel were first used for filling joints in the pavements in London in 1869 and in Liverpool in 1872. Probably the first pavements of this character in this country were laid by the Dock Department of the City of New York in 1881. Stone pavements are laid where the traffic is heavy, and when laid as above described, should last twenty-five to thirty years.

Brick Pavements:—Brick was first used as a paving material in this country in Charlestown, W. Va., in 1870. These bricks were laid on oak planks, which themselves were laid on a bed of sand. The pavement proved quite satisfactory and brick were gradually adopted in other cities in the vicinity. In the central West where natural paving material was scarce and expensive to obtain they have become very popular, the clays of Illinois and Ohio being especially adapted for paving brick. The bricks themselves have been laid in a number of ways according to the traffic to be sustained and the ideas of the controlling officials. A common practice under light traffic is to lay a course of brick flat, bedded in sand, and upon these lay the best brick on edge. The best method, however, is to use a concrete base and have the joints filled with some impervious material. This can be coal tar, asphalt or Portland cement. Considerable trouble has arisen in many cases where Portland cement has been used by the expansion of the pavement and the rumbling sound, caused probably by the lifting of the pavement from the concrete. It would seem strange that brick which must have been submitted to a temperature of 1800 to 2000° F. should expand when laid in a pavement when the temperature of the air is but 120 to 125° F., but such is a fact, and the practice to-day is whenever cement is used for the joints to have expansion joints of asphalt or some other bitumen every twenty-five or thirty feet across the street and longitudinally against the curb. Brick pavements have not been used so much in the East as in the West, as the clays in the former section are not suitable for making paving brick and the expense of transporting them from the West is heavy. They make a

smooth but a more noisy pavement than asphalt, and in the East one that is more expensive. They have been used quite extensively in the smaller cities, but Philadelphia is the only large city in the East that has adopted them to any great extent.

Wood Pavements:—It may seem strange after what has been said that wood pavements should be considered a standard paving material, but when it is understood how different the present

Wood Pavement. Borough of Brooklyn, New York City.

wood pavements are from those of the past the apparent paradox will be explained. The first wood pavements were laid of spruce or hemlock, the material taken without any special care and laid in an ordinary manner. With the Nicholson pavements both the character of the blocks and the manner of laying had been much improved; the blocks being of pine and laid on planks which themselves were placed on a sand cushion. The cedar block

pavement laid in the West was simply formed of blocks six inches long cut from cedar posts with the spaces between filled with tar and gravel.

Some seven or eight years ago the officials of Indianapolis in considering wood pavements decided that if treated wooden blocks would make a good pavement anywhere they would in Indianapolis. They therefore laid pavements, treating the blocks with creosote oil, the specifications calling for 10 lbs. to the cu. ft. These pavements were quite satisfactory, but swelled when being exposed to water and sometimes bulged considerably. This was undoubtedly caused from the fact that the blocks were imperfectly treated and the creosote itself was probably of an inferior character, as later pavements laid in the same way, but with more care, gave good results. It was found, however, that the creosote being an extremely volatile material evaporated and left the blocks porous and subject to moisture. The problem then was to hold the creosote in the wood so as to prevent absorption of the moisture and yet obtain the preservative properties of the oil. The block known as the Kreodone block was then made and used with good success in Indianapolis. This block was treated with creosote and some other more stable substance, probably an asphaltic substance, which prevented the volatilization of the oil and thus preserving the wood. In the East another form of treatment has been adopted quite extensively, which is known as the Creo-Resinate process. These blocks are treated with a compound made of one-half creosote oil and one-half resin, 20 lbs. to the cubic foot being injected into the blocks. The idea of the resin is to preserve the creosote in the blocks and so preserve the block itself from decay. A pavement of this kind was laid on Tremont street, Boston, some six years ago, and now shows almost no wear, although it has been subject to quite heavy traffic. There seems to be no question that this form of pavement will be extensively used in the near future. It has been laid during the past year on several of the heavy traffic business streets of New York.

The pavement for which wood blocks are specially adapted is for the paving of bridges on account of its durability and its lack of weight. A well treated block should have a specific gravity of a little more than one. These Creo-Resinate blocks have been used on the new Williamsburgh Bridge across the East River

and after having been in use for two years show very little wear. Some three years ago a small bridge in Brooklyn was paved with these blocks where the traffic was so heavy that ordinary planking wore out in some six or eight months; the present pavement is in fairly good condition now and would have shown very little wear had the foundation been even and solid, but it was laid on the old planks, which were uneven and shaky, so that the blocks soon broke into small pieces, but as pavement as a whole main-

Macadam Street. Borough of Brooklyn, New York City.

tains its entirety. If the treatment of the blocks as described above will prevent all decay a pavement of this kind should last for many years on a resident street, and the proprietors of the pavement are prepared to apply it on the heaviest traffic streets. One great advantage of it is that it is the least noisy pavement of any in use. Its greatest disadvantage is its slipperiness. This pavement has cost in Brooklyn, having five years' guarantee, about $3 per sq. yd.

Macadam Pavements:—The macadam pavements are not standard and are too well known to require any detailed descrip-

tion. Their durability is governed wholly by the quality of the stone that is used in their construction. They are noiseless, easy for horses and cheap, but are extremely dusty, requiring constant sprinkling if they are to be kept in good condition. It would probably cost five or six cents per square yard per year to keep macadam pavements properly sprinkled, which is more than the average cost of asphalt in an ordinary good condition for total repairs. Attempt has been made to prevent dust on macadam pavements by treating the surface with coal tar. This has been quite satisfactory in many instances, but has not been tried sufficiently to afford basis for an intelligent opinion as to its durability. Another material for treating is known as Westrumite—a substance patented by a German named Westrum. This substance consists of asphalt, resin and some ammonia which is mixed with water and sprinkled on the street. The theory is that it will form a sort of gum and bind the dust together. This has been used somewhat during the past year but not enough to show just how practical it is. Some time ago a contractor in the East who had been connected with the laying of asphalt pavements took up the problem of improving macadam with coal tar. Strange as this may seem, instead of improving the macadam his labors resulted in the development of an entirely new pavement known as the Bitulithic Pavement.

THE BITULITHIC PAVEMENT.

This pavement was first introduced in the year 1901 in Pawtucket, R. I., on Park Pace, having a 3% grade, and on Harvey street, having a 12% grade. It is made of crushed stone and bitumen, the particles of stone being mixed in certain scientifically predetermined proportions as to sizes so as to provide a maximum of density and minimum of voids, so that the resulting bituminous concrete pavement is nearly as dense as a block of solid stone, with a surface that offers as little resistance to traction as asphalt, but one that is not slippery, because the fine stone used in the finish course provides a gritty surface similar to macadam, which affords secure footing for horses at all seasons.

The sub-grade for the Bitulithic is prepared as for other pavements, and the foundation may be either bituminous or hydraulic concrete, depending on the character and solidity of the sub-soil.

The concrete foundation is prepared as for asphalt except that when used with the Bitulithic wearing surface it is roughened by tamping crushed stone into the surface before the mortar has set so as to provide a bond and prevent the surface from rolling or creeping.

The bituminous foundation consists of broken stone or slag from two to three inches in size, laid to a depth sufficient to meet the demands of the traffic to which the proposed street may be subjected, usually from four to six inches. The broken stone is then thoroughly compressed with 15-ton road rollers. Over this compressed foundation is spread a coating of heavy bituminous cement, or binder, which serves to firmly unite the foundation and wearing surface.

The wearing surface, after thorough compression, consists of two inches of the hardest broken stone available, varying in sizes from one or one and one-half inches down to an impalpable powder, the various sizes of the smaller stone, sand and impalpable powder being provided to fill the spaces between the larger stones. The proportions of the various sizes of material used are predetermined by physical tests with a view to obtaining the smallest percentage of air spaces or voids in the mineral mixture, and vary with the character and size of stone used in each particular case. After the proportions have been determined, the crushed stone is passed through a rotary dryer, and is then mechanically screened and separated into six sizes. The proper proportion by actual weight of each of these sizes is run into a mixer and there combined with a bituminous cement, which is also accurately weighed in the proper proportion. After being thoroughly mixed, and each particle of the mineral aggregate properly coated, it is hauled to the street, spread and thoroughly compressed with heavy steam rollers.

While the compressed Bitulithic surface is still warm, a flush coat of quick drying bituminous cement is applied, thoroughly sealing it and filling all pores in the surface, thus preventing the penetration of moisture. There is then applied a thin layer of hot, finely crushed stone, varying in size from one-fourth to three-fourth inch in size, according to the degree of roughness desired in the surface. The pavement is again thoroughly rolled and the street is finished and at once ready for traffic.

The Bitulithic pavement has been laid in 102 cities in the

United States and Canada, ranging in climatic conditions from Glace Bay, Nova Scotia, to Shreveport, La., and from Portland, Oregon, to Atlanta, Ga., to the extent of over 4,000,000 sq. yds. —about 200 miles of street 30 ft. wide; it has been subjected to all classes of traffic in these varied climatic conditions and has successfully met the requirements in each case.

The different kinds of pavements having been considered, the next problem is the adopting of the one best suited for any particular street. An attempt has been made to study the properties of the different pavement materials so that they can be applied intelligently to any street when exact conditions are known. The following table gives the result of this study:

Characteristics for a Perfect Pavement.	Percentage	Granite A	Granite B	Asphalt	Brick	Belgian	Macadam	Cobblestone
Cheapness	14	2	4	4	3	5	7	14
Durability	21	21	17	15	13	17	7	15
Easiness of cleaning	15	11	8	15	12	7	5	2
Light resistance to traffic	15	7	6	15	12	6	6	4
Non-slipperiness	7	6	5	3	6	3	7	5
Ease of maintenance	10	10	7	6	6	7	3	2
Favorableness to travel	5	3	2	5	4	2	5	0
Sanitariness	13	9	7	13	11	5	5	2
Total	100	69	56	76	67	52	45	44

In this table the characteristics of a perfect pavement are given in the first column and in the second the different values of each characteristic. The following columns show the values for the different kinds of pavements—Granite A is a granite block pavement, laid on a 6-inch concrete base with tar and gravel joints. Granite B is the same pavement, but laid on sand with sand joints. As the table was made some years ago, wood does not appear, but the different materials illustrate the principles of its operation.

The application of the above table can be illustrated in several ways.

Assume for instance a street over which the traffic must be

heavy and continuous. Ultimate cost is of great importance. It overrules first cost. Light resistance to traffic and foothold for horses are ruling elements, so that a given power may move its maximum load. The items first to be studied are, then: Durability, maintenance, traction, and the non-slippery property. Consulting the table and combining the values of these items, granite A has a value of 44; granite B, 35; asphalt, 40; brick, 37; Belgian, 33; macadam, 23, and cobble stone, 26.

Consider next a residential street, built up with homes whose owners have means sufficient to afford the best of anything they desire, and, while not wishing to be extravagant, do want and expect the best pavement that can be laid without regard to expense. This is an entirely different proposition. Cost, durability and maintenance, so important before, can be left out of consideration altogether. Easiness of cleaning, non-slipperiness, favorableness to travel and sanitariness are the governing characteristics. Working as before, granite A has 29; granite B, 22; asphalt, 36; brick, 33; Belgian, 18; macadam, 12, and cobble, 9. Asphalt possessing all the desired properties in so high a degree should be selected without much question.

It is also important to know just what each pavement will cost after it has been laid. Let C equal the cost per square yard, I equal rate of interest to be paid, N equal the life of pavement, R equal the total cost of repairs, and A the amount to be paid in each year to create a sinking fund to equal C in N years.

$$A + CI + \frac{R}{N} = \text{annual expense.}$$

For granite A: C = \$2.50;
I = .035;
R = .60 — an amount sufficient to relay the pavement once during life;
A = .064;
N = 25 years.

Substituting in the equation,

$$\$0.06425 + .0875 + \frac{0.60}{25} = \$0.17575 \text{ for first period.}$$

For the second period, assuming the value of the concrete to be \$0.70 per square yard, making the cost of relaying \$1.80 per

yard, the annual expense is found as before to be \$0.13326, or for fifty years an average of \$0.154.

In this way the actual cost of a permanent pavement of any kind can be determined.

It is often desirable to know positively when the cost of repairing a pavement has become so great that it would be economical to relay the pavement. This can be determined by the same formula, as its result governs the cost of maintaining the pavement perpetually, so that when the annual repairs equal or exceed the perpetual annual cost, it is time to repave.

Take for instance an asphalt pavement, and let $N = 15$ years, $C = 1.50$, $I = 3\frac{1}{2}$ and $R = 0.40$. Then A will equal .0807 and the equation becomes $\$0.0807 + .0525 + .0267 = \$0.1599$; or if the street be repaved it will cost annually \$0.16 till it is renewed. Consequently if the life of asphalt be correctly assumed at 15 years, it should not be repaved until the annual cost approaches \$0.16 per square yard. Assuming the life to be 20 instead of 15 years and applying the formula as before, the annual cost will be reduced to \$0.1356 per yard.

The author believes this is the true scientific way in which to determine when an asphalt pavement, from an economical standpoint, should be relaid.

ALUMENUM COATED SHEETS.

A comparatively new product, named Alumenum coated steel sheets, is now coming into prominence for a large number of purposes for which sheet metal work is used. This material stands relatively between galvanized iron and copper, being better, it is said, than the galvanized iron and not as expensive as sheet copper. It has been tested for some years under most trying conditions with highly satisfactory results. The two most important qualities in sheet metal working are fully met, in that it will double seam without scaling and will solder freely. Alumenum coated sheets are used largely for tanks of various kinds, reservoirs, boilers, furnace and smoke pipes, oven linings, flues, &c. In the automobile trade its use for hoods, fenders, and bodies as well as for cylinder jackets and various other parts is becoming quite large. These sheets are rustproof, retain their color, and the coating will not peel off, even when subjected to a high degree of heat. A Philadelphia firm is placing on the market the original Alumenum coated steel sheets, which it is making in all gauges from Nos. 10 to 30, standard sizes being kept in stock, while special sizes are made to order.—*Iron Age.*

Section of Physics and Chemistry.

(*Stated Meeting held Thursday, March 28th,* 1907.)

Theory of Dyeing.

J. Merritt Matthews, Ph.D.

Dyeing is essentially a process of coloring substances. In a limited sense it is usually taken to refer to the coloring of various textile fabrics, though broadly speaking it is not really limited to any definite material. We have not only the dyeing of textile fabrics, but also the dyeing of leather, paper, wood, feathers, horn, ivory, marble, confectionery, food-stuffs, wines and liquors, soaps, candles, straw, eggs—and coming down to more human elements, even the hair and complexion of the weaker sex lend themselves as fit materials for the practice of the dyer's art; and even our own flesh, heir to many evils, is not immune from the tatooer's colors. Dyeing, however, does not include every operation of coloring substances. A proper distinction must be made between dyeing and painting; in the latter, a color is applied to the *surface* only of the substance, either for the purpose of artistic ornament or as a protection; in dyeing, however, it is the material itself of the substance that is colored, not merely the surface. Even in the printing of fabrics, the operation is essentially a dyeing process, the fabric (or other material) being dyed in places only; and a distinction must here be drawn between textile printing and printing used in the sense of book or paper printing, which is only the application of a pigment to the surface and would come under the general term of painting, using blocks of type instead of brushes.

Dyeing is also to be distinguished from painting in that it applies color through the medium of a solution of the coloring-matter; whereas in painting the coloring-matter is an insoluble pigment held in suspension in a suitable liquid medium. The application of the color in painting is essentially a mechanical operation; in dyeing, however, the application of the color usually involves

rather complicated chemical processes, and is itself more or less of a chemical reaction.

Though this general conception of dyeing is rather well understood, there is, nevertheless, a great deal of confusion existing concerning the exact nature of the phenomena which deals with the dyeing process. Many different theories have been advanced concerning the relations between the dye-stuff and the substance dyed, but though many of these theories may explain certain examples of dyeing, none of them offer a satisfactory and complete explanation of the whole general field of dyeing. This may be accounted for by the fact that the dye-stuffs employed are of varied chemical composition and properties, and a theory which would satisfactorily explain the behavior of one dye-stuff would be wholly inadequate to explain that of another possessing entirely different chemical characteristics. Furthermore, if we confine our attention even to the sole consideration of the textile fibres as the substances to be dyed, we meet with wide variations in chemical characteristics as well as differences in physical properties and structure; and hence, it may easily be understood that a theory which would explain the manner of applying dye-stuffs to one fibre would not necessarily be the proper one to explain the dyeing of another kind of fibre. Wool, for example, is very different from cotton in both its chemical characteristics and its physical properties, and though a chemical theory of dyeing with respect to wool with acid and basic dyes might be quite acceptable, nevertheless, it would not serve in any manner to explain the relation between cotton and the substantive dyes.

The process of dyeing, in the first place, must be viewed with reference to the nature of the dye-stuffs. These are capable of classification under rather well defined groups, which are as follows:

(1) *Acid dyes,* or those in which an acid nature is characteristic. These are to be considered as salts of certain organic acids (color acids) with such bases as soda or potash. They are usually dyed in a solution acidified with sulphuric or acetic acid, and are readily taken up by the animal fibres, wool and silk; but exhibit little or no attraction for the vegetable fibres, such as cotton and linen.

(2) *Basic dyes,* or those in which a basic nature is characteristic. They are considered as salts of certain organic bases (color

bases) with such acids as hydrochloric and sulphuric acid. They are usually dyed in neutral baths and exhibit a strong attraction for the animal fibres, though but little for the vegetable fibres.

(3) *Substantive dyes,* which appear to be of a neutral chemical character, and are derivatives of benzidine or other diamine compounds. They are dyed in a neutral solution, and show an especially pronounced attraction for the vegetable fibres, though they also dye on the animal fibres, in many cases just as well.

(4) *Mordant dyes*; these are also of a neutral character, but possess the property of forming insoluble color-lakes with metallic bases, like the oxides of iron, chromium and aluminium. They are mostly derivations of anthracene and analogous bodies. They show no true dyeing properties towards any of the fibres, but require a proper mordant.

(5) *Pigment dyes,* consisting of insoluble pigment usually precipitated within the cells of the fibres by double decomposition between two soluble salts, such as the dyeing of chrome yellow. These pigments are mostly of a mineral nature.

(6) *Vat dyes,* such as indigo, aniline black, and a few others of minor importance. The insoluble coloring-matter is usually formed by oxidation of some compound absorbed in the fibre.

These six classes, I believe, will include about all methods of dyeing which are liable to be encountered. It will be noticed that the acid and basic dyes exhibit well defined chemical characteristics, and as they dye only the animal fibres to any extent, it is supposed that they enter somewhat into a chemical combination with the fibre. That is to say, the acid dyes combine with the basic constituent of these fibres and so form color-lakes of a definite chemical function. And as these animal fibres also possess acid characteristics, they furthermore combine with the basic dyes in a similar manner. To what extent this chemical union between the fibre and the dye-stuff determines the power of the coloring-matter to dye the fibre, is open to question; that it is the sole factor in the dyeing process, however, cannot be substantiated, though there is no reason to doubt but that it exerts considerable influence in giving, at least, *direction* to the dyeing reaction. This chemical theory cannot be applied to the dyeing of

the substantive colors, either on the vegetable or animal fibres, and we must look for a broader and more general conception to include this class of dyes.

If we view the fibres as gelatinous substances, such as a stiffened jelly or glue, we can conceive of the possibility of them being able to dissolve substances within themselves, forming as it were a solid solution. A broad conception of dyeing is to consider the dye-stuffs as actually dissolving in the substance of the fibre, hence the process of dyeing may be said to be a phenomenon, primarily dealing with solutions. Gelatinous substances, though they are really solid, also seem to possess some of the characteristics of liquids, especially with reference to their power of dissolving substances. Starch paste, jellies made from vegetable gums, or animal gelatine or glue, all have the power of dissolving various substances, such as metallic salts and dye-stuffs. Hence it may be perfectly proper for us to say that silk, wool, and cotton are capable of *dissolving* mordants and dye-stuffs in the same general manner that any other solvent would. The affinity of a dye-stuff for a fibre becomes nothing more than the power of the fibre to dissolve the coloring-matter out from its solution in water—in which form the dye-stuff is applied. When the fibre has a strong solvent action on the coloring-matter we say it has a strong "affinity" for the dye-stuff, and if its solvent action is only slight, we say that the "affinity" is weak. The study of the theory of dyeing then becomes a study of the sets of relations between the fibres and water, on the one hand, as solvents, and the dye-stuffs and mordants, on the other hand, as the substances dissolved, and this comes within the strict province of physical chemistry and the theory of solutions.

The animal fibres, wool and silk, as a rule, exhibit solvent properties which are very similar; and on the other hand, cotton, linen, and the vegetable fibres in general, appear to exhibit similar properties in this connection. This may no doubt be conditioned very largely by the chemical nature of the two classes of fibres, though we also have instances where there appears to be distinctive properties between wool and silk. Silk, for instance, may be dyed with indigo carmine from an acidulated bath, and takes up the color quite readily; but if a mixture of silk and wool be dyed in such a solution, the wool takes up the color almost exclusively, the silk only becoming slightly tinted. This

is explained by supposing that the wool dissolves the dye-stuff much more readily than the silk.

There are several factors which may influence considerably the solvent action of the fibre for the coloring-matter. One of the principal of these is heat. As a rule, dyes are much more soluble in the fibres at a boiling temperature than at lower ones; on this account the dyeing process is mostly carried out in a boiling solution. Wool, for instance, if dyed in a cold solution of naphthol yellow will take up but little color; but in a boiling solution of this dye-stuff the fibre becomes colored an intense yellow. The addition of various chemicals may also influence considerably the solubility of the coloring-matter in the fibre. In the case of the general class of acid dyes, the addition of sulphuric acid to the dyebath may be considered as greatly facilitating the solubility of the dye-stuff in the animal fibres. In some cases, the addition of alkalies somewhat increases the solubility of the coloring-matter in the fibre; this is the case with certain substantive dyes in relation to the cotton fibre. The addition of such neutral salts, like common salt or glauber salt, also effect this purpose. The action of these additions to the dyebath will naturally vary with the chemical nature of the substance added; in some cases there may be a chemical reaction with the dye-stuff leading to the formation of compounds which are more soluble in the fibre. In the case of acid dyes, the dye-stuff itself is a salt of a color-acid; when sulphuric acid is added to the solution, the salt is decomposed with the formation of free color-acid, and this latter compound is more soluble in the fibre than the color-salt, hence the addition of sulphuric acid causes the fibre to be dyed more deeply. In some cases there may be no chemical reaction with the dye-stuff, but the increase in the dyeing properties may be due to other causes. When common salt, for example, is added to the dyebath with substantive dyes, it does not effect any decomposition of the dye-stuff; it does, however, greatly diminish the solubility of the dye-stuff in water, which results in a proportionately large increase in the relative solubility of the coloring-matter in the fibre.

The proper discussion of all the various factors entering into the theory of the dyeing process would be far too extensive and technical for me to consider in this brief review of the subject; but to show you in some manner the wide ramifications of this

matter, I will sum up the following factors which may be said to enter into the question at one stage or another:

(1) The *solution* factor, which may be defined as the difference existing between the degree of solubility of the dye-stuff in water and its solubility in the substance of the fibre. This may be called the "affinity" of the dye-stuff for the fibre.

(2) The *fibre* factor, depending on the nature and condition of the material being dyed.

(3) The *dye-stuff* factor, depending on the chemical nature of the dye-stuff used.

(4) The *chemical* factor, which includes the influence of any chemical reaction which may occur between the fibre and the dye-stuff.

(5) The *temperature* factor, which describes the effect of the temperature of the bath on the relations between the dye-stuff and the fibre.

(6) The *salt* factor, which relates in a similar manner to the effect of the presence of certain neutral salts in the bath on the dyeing process.

(7) The *mordant* factor, or the influence of the presence of certain metallic compounds in the fibre on its affinity for the dye-stuff.

(8) The *capillarity* factor, a physical property of the dye solution which has to do with the force with which this solution is mechanically absorbed by the fibre.

(9) The *osmosis* factor, another physical relation between the dye solution and the fibre, it representing the force with which the dissolved dye-stuff tends to pass through the cell-wall of the fibre.

(10) The *concentration* factor, depending on the strength or concentration of the dyebath with reference to the amount of dye-stuff in unit volume of solution.

(11) The *bath* factor, or the ratio between the amount of substance being dyed and the amount of dye-liquor.

(12) The *surface-tension* factor, existing between the dye solution and the colloidal substance of the fibre.

(13) The *dye-stuff mass-action* factor, being the influence of the relative amounts of two or more dyes in the same bath.

(14) The *fibre mass-action* factor, or the influence of the relative amounts of two or more fibres in the same bath.

ELECTRICAL SECTION.

(*Stated Meeting held Thursday, February* 21, 1907.)

Recent Developments in Wireless Telegraphy.

Dr. Lee de Forest.

No single subject before the world to-day is more typical of the speed and spirit of the times than the brief history of the Wireless Telegraphy.

Already we have progressed so far in the development of this science that it can be classified under several heads. Its leading exponents as a class considered highly specialized must already themselves specialize in the several branches of the new art.

There are investigators who devote their entire attention to the perfecting of the transmitting apparatus; others are authority on syntonization and methods of measurement; another class has specialized on receivers; others in the refinement of the mechanical details on which to a considerable degree the commercial success depends.

The bibliography of the Art already embraces nearly a thousand volumes and pamphlets, and a portion of the contents of most of our technical journals is devoted each week to "Wireless" items.

In these nine years since the first actual application of Hertzian wave telegraphy we have seen every navy equipping its more important vessels, each government starring its coast-line with stations of great or little power; the armies of the leading powers equipping their kite and balloon corps with field sets, and twice now the great powers have convened in International Conference to frame regulations and codify laws whereby the development and operation of this young science may be wisely directed or paternally regulated.

But surely this progress is not entirely accounted for by reference to the intense commercial competition of our times. There is a fascination in the task which stimulates—an etheric "call of

the wild" which has spurred us on, such as workers in few fields can hear.

In poor and painful beginnings, conceived of small knowledge and great faith, we have heard faint voices persistently calling. In the patience and poverty of humble laboratories we have seen visions and dreamed dreams. Then too the humanizing element of such work has not been lost sight of. It is a pride to know that to-day the distant mariner, lost by a hundred horizons, may hold converse with his haven by means of a small instrument and antennæ such as his ship can carry; and that when night has hidden even the waters of the sea-world from his view, this wireless voice reaches farther than by day, for thus kind Nature rules; so that a passenger off the southern coast may sometimes hold converse direct with home cities, far inland, even to Cleveland or St. Louis.

Latest and most novel of all branches of electrical science, Wireless Telegraphy has outstripped its keen chroniclers and found the printing-press a laggard; so that to-day, with scarce a dozen worthy exceptions, most of the treatises are already out-of-date.

We no longer look with interest or patience upon the chapters of a host of histories detailing the coherer, the "jigger," the simple antennæ, spark-gap and interrupter, the Morse printer, and a whole curiosity shop of other devices which not five years ago were seriously considered as embracing the essentials and the horizon of Wireless.

That famous log of the Italian man-of-war "Carlo Alberta," by Lieut. Solari, and its more interesting and equally veracious "Supplementary Log," by Mr. Maskelyne, have long ceased to astound or amuse.

In the text-books of the schools is recognized the position which this newest branch of electrical development has acquired, and although too many of our professors deem their duty done when the Branly filings-tube and the simple transmitter are described, yet the student is thereby given at least an inkling of the possibilities awaiting those who will qualify to enter in earnest this fascinating field.

It is obviously futile then to attempt in this brief paper a description of any but the most recent of developments in Wireless, and I shall in dealing with these, take it for granted that all

of my hearers are abundantly familiar with the last century apparatus. And I will only mention the good old days when Finlay and Willoughby Smith, Preece and Lodge toiled with conduction and induction methods, and Dolbear, employing excessively low frequency vibrations, first used elevated conductors at sender and receiver.

Popular interest has ever been centered upon the development of the receiving device. It is a striking commentary upon the keen competition in our electrical fraternity that since the limitation of the coherer, and the auto-coherer, or microphone receiver, were recognized, no less than six different genera of receivers have been discovered or made commercial, each of these classes differing from all others, not in detail of construction, but in the fundamental physical or chemical principle involved in its operation.

Some time lag was required for the ideas of certain pioneers to become "decohered"—They would stick to the filings and the tapper, the printer with the slow speed and the guess work inseparable therefrom; but the demonstration of the manifold superiority of a detector automatically restored to sensitiveness, the telephone receiver available therewith, the rapid and accurate sound reading by competent Morse operators—was too emphatic to long fail to convince.

First after the microphone, or auto-coherer, (itself extremely sensitive but equally erratic in operation) came the various forms of "anti-coherers," devices where either by the fusing of minute metallic bridges (Schaeffer plates) or by the same immersed in electrolytes and disrupted by gas bubbles, the local current was interrupted by the Hertzian waves. All of these, while at times marvelously sensitive, lacked reliability.

The magnetic detector was next produced; regular in action in certain of its forms, but lacking in sensitiveness, and inefficient. The bolometer, or hot-wire "barreter," utilized heat-energy of the received oscillations to raise the resistance of a platinum wire of microscopic diameter. This was moderately sensitive, beautifully adapted to quantitative measurements, but, alas, so ephemeral! A lightning storm in the next hemisphere seemed most disastrous to this molecular thermometer.

The electrolytic responder (appropriately described as the "polariphone," because it depends for its operation upon the

effect of the electric oscillations upon the polarization at the minute electrodes) marked a great step in advance over all existing detectors. Its sensitiveness is considerably greater than all preceding types, its electro-static capacity is quite constant and, especially when the fine electrode is glass-jacketed and its exposed end immersed well below the surface of the electrolyte, this detector is reliable, and requires no adjustment.

Another class of oscillation detectors utilizes the peculiar electrothermic qualities of crystalline or pseudo-crystalline substances, notably silicon and psilomelane. Silicon may be used without a local battery. The unequal heating effect produced by the oscillation at the junction between silicon and a copper electrode gives rise to feeble local currents which can operate the telephone receiver, to produce an audible signal.

This class of receivers is certainly the simplest and least costly imaginable, and marks an approach towards that Utopian state of affairs so much heralded by the popular press when each of us will carry a responder in his vest pocket, a telephone on his head; and with steel-rod umbrella in his hand, and lead soles upon his shoes, shall be within telephone reach of every other unfortunate similarly equipped!

The sixth type of receiver of which I speak employs neither solid nor liquid as its wave-responsive element, but gas, more or less attenuated and rendered conducting by heat, or electrical excitation, or by a combination of both. The gas flame, the heated vapors in an arc, or about an incandescent lamp filament are examples of a gaseous medium extremely sensitive in its current-conducting qualities to the influence of the electrical pulsations. The name, "Audion," is now generally accepted as descriptive of this class of Wireless receiver. In sensitiveness, reliability, and extremely close tuning qualities, it excels even the electrolytic responder.

In contrasting the relative refinements attained to-day in transmitting and receiving apparatus, Eichorn well says: "If the sender had anything approaching the ideal properties of such a highly developed receiver, the sphere of Wireless Telegraphy would be capable of far wider extension than now possible."

While laboratory research has been so occupied exploring the range of physics for a new and better wireless receiver, the mathematicians and pure-theorists have been little less busy in

developing methods of measurement, and in the analytical investigation of the laws involved in transmission and syntonization.

Max Wein, Abraham, Drude, Slaby in Germany, Poincare in France, McDonald and Fleming in England, and Pierce in America, have delved more or less deeply into the application of Maxwell's theory to the intricate and intensely interesting phenomena observed or to be expected.

Unfortunately the pressing demands of commercial development have allowed the practitioner in the field, who alone has the management of apparatus or facilities adequate for testing these theories, little opportunity for such research work. He is too often driven to the "cut-and-try" method, and many important questions of theory have gone unanswered; problems whose actual solution would doubtless greatly clarify our ideas and lead to improvements of utmost commercial value.

For example, aside from the brilliant but far too limited research work in measurements by Duddell and Taylor in England, of energies actually received with various arrangements of antennæ and earth connections, almost no progress has been made towards actually plotting the fields of force of these waves and the manner of their propagation.

Their work has pretty well established that the energy of the electro-magnetic wave varies inversely between the first and second power of its distance from the source. The wave, therefore, must expand not as the surface of a hemisphere, but of a hemisphere very much flattened. They have established the correctness of the theory, first advanced by Taylor and later by Blondel, that the feet of the electric lines of displacement are grounded to the conducting surface and slip along in the form of minute currents over the gradual irregularities of this surface, while the displacement lines, themselves nearly perpendicular to the earth's conducting surface, will cut through obstructing masses if these be non-conductors, but be reflected from or absorbed in eddy currents within the surface of *conducting* obstacles.

Many observed paradoxes in the transmission by Hertzian waves are thus made clear, but an enormous amount of data must be collected by costly experiments, some to be conducted in the upper atmosphere, before the complete theory of every-day transmission under great varieties of condition can be framed.

One great desideratum which has been before us from the first

is the discovery of a method whereby the propagation can be limited to any desired direction, thus greatly increasing attainable distance, and enormously simplifying the problems of mutual interference.

The original parabolic reflector of Hertz offers a clear solution but greatly limited in distance attainable, owing to the enormous dimensions which such a reflector for long waves would require.

The horizontal wave-chute or artificial ground net is yet unable to solve the problem. Prof. Braun has done some intricate and extremely pains-taking work with his system of several vertical transmitting antennæ, the currents in these being properly displaced in phase, so that their resultant wave is intensified in certain directions and neutralized in others. The accuracy demanded by this method has thus far prevented its successful operation.

Quite recently considerable attention has been drawn to experiments with the horizontal antennæ lying near the earth's surface both for receiving and sending. It has been found that the maximum distances of transmission with such antennæ lie in the direction of the horizontal wires, but these distances are enormously less than those attained with the same length of vertical antennæ. A compromise between the two is the oblique transmitting antennæ, inclined say at an angle of 30° to the earth's surface, and lying in the vertical plane which passes through the receiving station.

The writer began experiments with such antennæ in 1902, and since then has demonstrated the surprising extent to which masses of horizontal conductors, such as groups of telegraph wires and railroads, act as wave chutes to confine a large amount of the radiated energy to a zone co-axial with such lines. It is by virtue of this effect that the surprisingly long distances in transmitting wireless signals to moving trains are attained.

In certain work carried on at Chicago and St. Louis, in 1905, messages were clearly received on board express trains of the Chicago and Alton Railroad when at full speed, 35 miles from the transmitting stations.

Even when the telegraph wires were broken down and lying along the roadside, they, in conjunction with the iron rails, act admirably as wave conductors. And herein lie possibilities of utmost value to railroad companies to enable train-dispatching and

other telegraphic service by means of "Wireless," when the inevitable sleet storms have paralyzed the wire service.

But the great problems of non-interference must look to a perfection of syntonization or tuning devices, rather than to unidirectional transmission, for their solution.

To accomplish this, so that any two of say a hundred near-by stations may be in communication without interference from the others, is theoretically simple; actually and commercially difficult.

To-day all recognize the value of the so-called "loose coupling" between oscillating and radiating circuits, whereby there is radiated a fairly persistent wave train of but a single, well-defined period. The best known circuits accomplishing this result to-day are embraced in the Stone system. If the four distinct circuits represented by the oscillating circuit and the antennæ, both at sending and receiving stations, are closely tuned to a single frequency it is possible to prevent interference from a foreign oscillation if its frequency differs by only one per cent. from the oscillation to which the four circuits are attuned, even though this foreign oscillation have an intensity fifty times that of the other.

This degree of selectivity is ample for all the commercial demands which Wireless Telegraphy will be called upon to meet for some time to come. But it is yet too early to say that we to-day anywhere actually carry on uninterrupted communication between any two of a hundred neighboring stations. For no matter how loosely coupled an oscillating circuit and its antennæ circuit may be, the trains of waves sent out from any oscillator utilizing the ordinary spark discharge are too rapidly damped to allow of the full benefits which this loose coupling should confer.

If the wave train is sufficiently persistent it is, of course, possible to so far separate the receiving circuit from its antennæ-earth circuit that no impulses received on the antennæ can awaken response in the detector circuit except those long continued rythmic pulsations with which the responder circuit is in absolute resonance.

To substitute for the old-fashioned, easily obtained spark discharge, an oscillator which shall receive from the source of power new supplies of energy exactly as fast as radiated; in other words, to substitute in Wireless Telegraphy a sustained organ-note in place of a damped piano-string or tuning fork vibration,

has long been desired. But attention of experimenters has been too much directed upon other features of the non-interference problem.

Duddell's work, in 1900, with the singing arc marked a giant stride towards this goal; but Duddell and the German physicists, some of whose work, less widely heralded, I believe preceded his experiments, were unable to generate oscillations from a direct current arc of sufficiently high frequency to be available in Wireless work.

They fixed 50,000 or 100,000 vibrations per second as the upper limit of frequencies attainable with the direct current arc in air. With oscillations of such enormous wave-lengths as this implied too small a proportion of the energy was radiated.

Poulsen by enclosing the singing arc in an atmosphere of hydrogen succeeded in enormously increasing the frequencies. The presence of hydrogen, however, is not a *sine qua non* in the generation of useful oscillations from such source.

It is not essential in order to secure all the benefits of closest possible tuning, that the wave train is absolutely undamped or continuous. It suffices if there be say 100 oscillations in the train before the current amplitude falls to one-half of its initial magnitude. The wave train from a single spark-discharge however may represent only ten or twenty oscillations. The damping factors of the receiver oscillating circuit, representing the ohmic resistance and losses in the wave-detector, determine the limit beyond which there is no increase of effect no matter how long continued the wave train may be.

Given either a continuous radiation of un-damped waves, or a radiation of damped wave-trains in groups whose frequency is above the audible limit, or at least above the frequency of the more essential tones used in human speech—and Wireless Telephony over commercial distances is comparatively easy of realization.

For a long time it was recognized that the receiver side of the problem was already solved. In 1899 when the writer, using an automatically restored responder, first heard in the telephone receiver in circuit therewith the sound of the transmitter spark, he recognized at once that every acoustic property of that spark was being faithfully reproduced in the receiver. If the spark varied in frequency, or loudness, spluttered or hissed, the fact was as

readily manifest in the telephone receiver as to the ear of one standing alongside the spark. In fact, if a glass chimney was put around the spark, as a muffler, the observer at the receiver recognized at once the same ringing, metallic sound thus produced. I remember this was most forcibly again brought to my attention when the spark at the Key West station was similarly muffled, although the listener was many miles distant!

It was recognized from the first then that to achieve Radio-Telephony by means of Hertzian waves, with the same apparatus and over distances at least comparable to those in Wireless Telegraphy, it was only necessary to "teach the spark to talk!"

The medium required for the transmission of radio-telegraph signals is ether at rest; that for radio-telephony signals is ether in a continuous state of vibration. And upon this normally uniformly agitated medium it is necessary merely to impose variations of disturbance. But the same result is obtained, as expressed above, if the normal disturbance, instead of being absolutely continuous, is alternating with periods of quiet, so rapidly that no resultant sound is heard at the receiver.

Now, to vary the state of normal disturbance in the ether, it suffices to vary the intensity of the spark itself, which is the origin of this disturbance, or to vary the intensity of the high frequency currents which are surging from the antennæ into the conducting surface of the earth. At this point of attachment to the earth the current densities are greatest, the potentials are least, and this point is therefore the most sensitive and effective place in which to insert the intensity-governing device. This is the method on which I am now at work.

In small sets it is sufficient to insert a microphone transmitter directly in this earth connection, and to talk, not too loudly, therein. For larger power this microphone should be replaced by other speech-varied resistance devices.

In radio-telephony the problems of tuning to prevent interference, etc., are the same as in the telegraph, with the notable exception that with signals of equal strength it is easier to follow the words of a voice through all manner of static and other disturbances than it is the monotonous signals of a telegraph code.

The radio-telephone has a wide field in all marine communication, between isolated points in mountain and rural districts, in military field operations, and wherever there is a relatively limited number of simultaneous conversations to be carried on,

or where it is undesirable or impractical to employ two Morse operators.

It would be rash, at this time, to attempt to predict its limitations as to distance. Inasmuch as it employs the same methods of transmission as Wireless Telegraphy it is certainly plausible to expect distances one-third or one-half as great by the Aerophone, as soon as one has learned to control by the voice the same amounts of energy as are now required in telegraphy; it being understood that with the Aerophone the maximum range can not well be greater than that over which the *weakest* impulse represented in the speech waves can produce an audible effect.

Time works vast changes in our performances and estimates nowadays. Witness especially how our wildest dreams of attainable distances of ten years ago are now sometimes accomplished by single kilowatt installations, such for example as when a ship in the Gulf off Florida sends its message direct to Denver!

While not seeking the robe of a prophet I will however venture the opinion that if trans-Atlantic telephony is ever accomplished it will be by means of the upper medium rather than by any sub-marine cable.

The one who works in "Wireless" must regard first of all the practical need of the art, must concentrate on every-day realities. He must deal with kilowatts and generators and earth-plates, foregoing the ever-present temptation to idle speculation. And yet many times in reverent mood he may look aloft into the sky at the spider traceries of his antennæ-wires, and wonder what and why they are, or by what mystery those simple lines have power to vibrate to the unseen waves, to send out even to the ends of the earth those strident yet all-inaudible messengers. And one may well marvel as he hears their voices in the tiny responder, some loudly distinct although from a thousand miles, and some as faint, as dim, as scarcely realized, as shadows on the wind.

Such are the marvels, such the promise, of this youngest science, which has grown so fast. In many lands far separate, by strange distant seas, these wireless masts now are planted, pinning down as it were into closer and more intimate contact the texture of the ether to the earth—uniting more and more the fabrics of the upper and the under worlds—interlinking *Thought* with *Reality*.

THE FRANKLIN INSTITUTE.

In Memoriam.

Samuel Sartain.

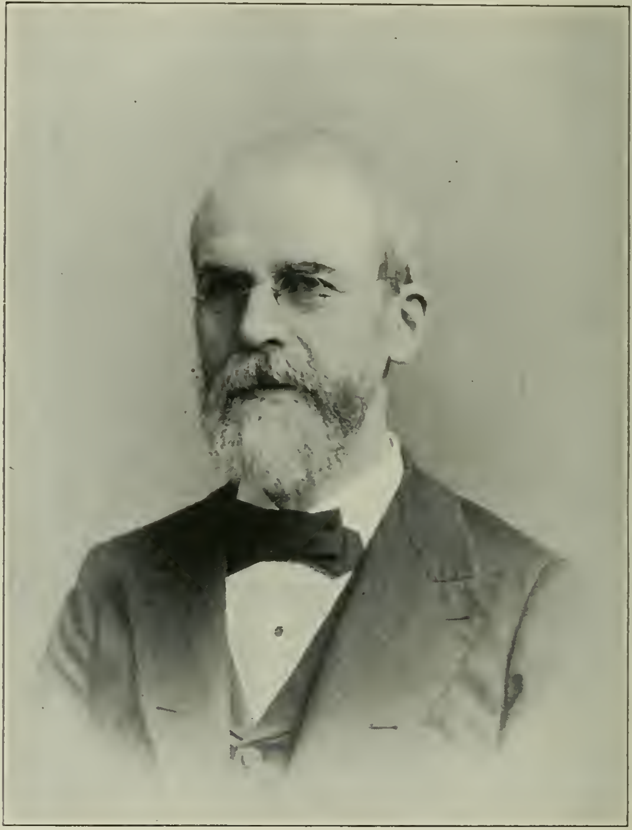
Through the death of Samuel Sartain, on December 20, 1906, there passed away from among the active spirits of the Franklin Institute one who, as a member of its Board of Managers during the past forty-one years, has surpassed all his colleagues in the duration of his continuous service and who had furthermore, during the last twenty-three years of that time, borne the added responsibility of duty as its Treasurer. In these directions alone, Mr. Sartain's labors in behalf of the Institute, and through it, for the community at large, have been of marked importance. But his services extended beyond the councils and the counting room of the Institute, into the fields of its distinctive work. He had for years been an assiduous member and, at one period, was Chairman of the Institute's Committee on Science and the Arts, in which capacity he took part in numerous of the scientific investigations undertaken by that committee. As chairman and reporter of various of the sub-committees charged with special investigations in the domain of the graphic arts, Mr. Sartain was the author of many valuable contributions to the literature of these subjects, which were published from time to time in the Journal of the Franklin Institute, and which, together, would make a considerable volume.

Samuel Sartain was born in Philadelphia on October 8, 1830. He was the eldest son of the celebrated engraver, John Sartain, who became famous as the earliest and leading exponent in America of that style of steel engraving known as the mezzotint.

The younger Sartain followed in the footsteps of his gifted father and eventually attained a degree of distinction in his profession which not only maintained, but also extended the fame of the Sartains as masters of their difficult and exacting art. He early envinced a marked talent for his work, studying both under the direction of his father and in the schools of the Pennsylvania Academy of the Fine Arts, and already in his seventeenth

year had so far mastered the technique of steel engraving as to successfully execute a three quarter length portrait of Benjamin West, after a painting by Harlow, on a 10x13 inch plate.

In 1854, he was commissioned by the Art Union of Philadelphia to engrave for their annual distribution a large plate, 18x23,



reproducing a painting by C. Schuessele, a winter coasting scene, entitled "Clear the Track." This engraving won for him a silver medal at an exhibition of the Franklin Institute and an "honorable mention with special approbation" at the World's Fair in New York. This work was followed by other of his large pro-

ductions, prominent among these being the plates entitled "One of the Chosen," after Guy; "Christ Stilling the Tempest," after Hamilton; "The Song of the Angels," after Thomas Moran; "Christ Blessing Little Children," after Eastlake; "Evangeline," and more recently "The Pompeiian Water Carrier." In 1896 he executed a large and very notable portrait of the late Simon Muhr for the executors of that philanthropist's estate, and less than a year ago he finished a large portrait of the late President of the Pennsylvania Railroad, A. J. Cassatt, both of which are very fine examples of his work in the line of portraiture.

The publication of illustrated biographical encyclopædias for cities, countries and states, which has developed so largely during the past twenty-five years, brought to Mr. Sartain an endless demand for his productions. He was throughout this period the favorite artist of the biographical publishers, and having the rare faculty of catching and bringing out the characteristic expression and likeness of the original, even where the copy was more or less defective, his work easily retained its leading place against the inroads of the photo-reproductive processes.

Besides his constant participation in the proceedings of the Franklin Institute, Mr. Sartain collaborated actively in the work of various associations more directly connected with his artistic pursuit. He was Vice-President of the Photographic Society of Philadelphia; Treasurer for many years of the Artists' Fund Society and closely identified with the Fellowship of the Pennsylvania Academy of the Fine Arts. His long and useful life was illuminated by a benign and sympathetic nature and he bore with an exceeding modesty, the esteem and the honors which his conscientious and successful efforts had gained for him.

Louis E. Levy, *Chairman;*
Henry R. Heyl,
Washington Jones,
Wm. H. Wahl.

Sections.

Section of Chemistry and Physics.—Stated meeting held Thursday, April 25th, 8 P.M. Dr. Wahl in the chair. Present, twenty members and visitors.

The Chairman introduced the speaker of the evening, Mr. Fred. E. Ives, of New York, who presented a communication on "A New Color Meter."

The speaker illustrated his remarks by means of blackboard sketches and exhibited a specimen color meter built in accordance with his plans, with which he made some demonstrations.

On Dr. Partridge's motion, duly seconded, the subject of the invention was referred for investigation and report to the Committee on Science and the Arts.

Adjourned.

E. A. PARTRIDGE, *Sec'y.*

Regular meeting held Thursday, May 2d, 8 P.M. President Dr. Robert H. Bradbury in the chair. Present, forty-two members and visitors.

The speaker of the evening, Dr. W. H. Walker, of the Massachusetts Institute of Technology, was introduced by the Chairman, and gave a communication on "The Chemistry of Cellulose."

The speaker illustrated his remarks with the aid of lantern photographs and a large collection of samples of products made from derivatives of cellulose.

The subject was discussed by Dr. Ed. Goldsmith, Dr. Wm. J. Williams and others.

The President extended the thanks of the meeting to the speaker and adjourned the session.

E. A. PARTRIDGE, *Sec'y.*

ELECTRICAL SECTION.—Stated meeting held Thursday, May 16th, 8 P.M. President Thomas Spencer in the chair. Present, fifty-six members and visitors.

The paper of the evening was read by Mr. C. O. Mailloux, of New York, on "The Electrification of Steam Railroads." The subject was profusely illustrated by means of lantern photographs.

After some discussion of the subject, the thanks of the meeting were voted to the speaker and the session was adjourned.

WM. H. WAHL, *Sec'y pro tem.*

The Franklin Institute.

(Proceedings of the stated meeting held Wednesday, May 15, 1907.)

PRESIDENT WALTON CLARK in the chair.

Present, twenty-one members.

Additions to membership since last report, six.

The first communication of the evening was presented by Mr. J. C. Trautwine, Jr., on Street Obstructions in Philadelphia, under the title of "A Libel on Philadelphia Refuted," illustrated by lantern photographs showing several of the city's prominent business streets, nearly two-thirds

of the width of which was occupied by builders' materials. The communication was freely discussed by the President, Prof. Lewis M. Haupt, Joseph W. Richards, Drs. Edward Goldsmith, W. J. Williams and Messrs. Louis E. Levy, Warner Walter, H. F. Colvin and the author.

Prof. Joseph W. Richards, of Lehigh University, by invitation, followed with an informal address, describing a number of the most notable of "Recent Advances in Electrometallurgy." In his remarks the speaker referred particularly to the following subjects—Electrolytic Sodium, Calcium, the De-tinning of Tinplate, the Electrolytic Refining of Gold and Silver, Electrolytic Lead Refining, Copper Refining, the Growth of the Aluminum Industry, Electric Iron and Steel Production, and the Electric Production of Zinc.

The communications of the evening were referred for publication and the authors received a vote of thanks.

The President called the attention of the meeting to an invitation received from the Michigan Agricultural College to participate in the commemoration of the 50th anniversary of the Institution. The Secretary was instructed to prepare and transmit a suitable acknowledgement of the invitation, expressing the felicitations and good wishes of the Franklin Institute.

Adjourned.

Wm. H. Wahl, *Secretary.*

Committee on Science and the Arts.

(Abstract of proceedings of stated meetings held Wednesday. March 6th, 1907.)

Dr. W. O. Griggs in the chair.

The following reports were adopted:

(No. 2389.) *Improved Thermometer Support.* T. F. Townsend, Philada.

(Report on this subject passed second reading and was adopted after amendment. As notice has been received that the case will be reopened, the abstract will be deferred until it has been finally disposed of.)

(No. 2399.) *Device for Relieving Forces Due to Inertia and Weight of Valve Gears.* Luther D. Lovekin, Philadelphia, Pa.

Abstract:—The invention of Mr. Lovekin is secured by Letters Patent of the United States No 775.573. dated Nov. 22, 1904. and is fully described in a paper published in transactions of the American Society of Naval Engineers, Vols XVI and XVII, No. 3. and also in a paper read before the same society by Ensign W. W. Smith. U. S. N., (August, 1906).

While Mr. Lovekin's design is not restricted in its application to a particular form of valve. it is particularly adapted to the ponderous piston valves, most frequently applied to marine engines. It consists of an external cylinder, concentric with the cylinders of the piston valve, and a balancing piston in said external cylinder, attached to a prolongation of the main valve stem, and so proportioned and ported as to practically balance

or neutralize the force acting on the reciprocating parts, due both to the weight and the inertia of these moving parts.

Mr. Lovekin preferably attached this balancing cylinder to the receiver of the compound engine, as the variable receiver pressure is found to best suit the conditions of varying velocity in the valve.

On large vertical engines, such as used in marine service, the weight of the reciprocating parts of the valve gear amount to several thousand pounds, and as high velocities are now usual, it can be readily known that a well devised balancing device is very desirable. The use of a balancing piston to neutralize the weight of the valve is an old and well known device. The use of the steam cushion to absorb the inertia of the valve has also been used. It was applied to the larger size of the Westinghouse engine many years ago, and is fully described in patent specifications No. 342,307 by F. M. Rites, under date of March 17, 1886.

A somewhat similar device has been used by Joy, in England, but as this exhausts or wastes steam in its action, it cannot be classed with the designs of Rites and Lovekin, neither of which exhaust steam in their operation. The design of Rites involves an enlargement of the diameter of the main piston valve, and a direct cushioning of the same in its cylinder, while the design of Lovekin, acting through a piston external to the main valve, and so designed that the location or arrangement of the regulating parts can be readily modified to suit the conditions of the service, offers a means of accomplishing the desired purpose in a very satisfactory manner. These balancing or assisting cylinders have been applied to several engines, both of the U. S. Navy and of the Commercial Marine, and are reported as having proved efficacious.

The report in conclusion recommends the award to the inventor of the John Scott Legacy Premium and Medal. *(Sub-Committee:*—James Christie, Chairman; T. Carpenter Smith and William H. Thorne.)

(No. 2393.) *Speed Indicator.* Hermann Frahm, of Hamburg, Germany.

Abstract:—In 1902, Mr. Hermann Frahm, chief engineer of a shipyard of Hamburg investigated the effect of torsional vibrations in propeller shafts, and found that the disastrous results were due to the well known property that elestic bodies possess of being set in vibration if they are subjected to rhythmic impulses, the frequency of which corresponds with the natural period of vibration of the bodies themselves. This is the principle of resonance. When he had found a means of suppressing the dangers arising from this cause, it occurred to him to devise a method of utilizing this same principle for the purpose of counting vibrations and measuring speeds. This speed indicator is the result.

An element of the indicator consists of a straight flat piece of watch-spring steel 3 mm. wide and 0.25 mm. thick. About 4 mm. of its upper end is bent over at a right angle, and in the angle is placed a small drop of solder, while the head is covered with white enamel to make it readily visible. A series of these springs of graduated lengths, varying ordinarily from 40 to 55 mm., are pinned and soldered in a slit cut in a rectangular bed. By properly arranging the lengths and altering the amount of solder at the head, any desired period of vibration between 35 and 100 per

second can be obtained. By the use of long and thin, or short and thick springs, the range of vibration can be further extended if desired. An assemblage or comb of such springs, attuned to graduated periods, is screwed to a rod 6.5 mm. square with 1 mm. space between each spring, and is held in a case so that the enameled ends are flush with a dial having a rectangular opening, wide enough to permit the vibrations, and with a scale to show the number of these vibrations. The length of the comb and the difference between the period of vibration of the adjacent springs can be varied to suit the requirements of any particular case, but this difference is usually made 2 per cent. The method of setting the comb in vibration depends on the number of revolutions of the machine to be counted. If these exceed a thousand per minute, the comb can be attached directly to the frame of the machine. If less than this, a cam with two or more tubes can be placed on the shaft and arranged to vibrate the comb.

If it is desired to indicate the speed of a machine at a great distance from it, this can be done by electrical transmission. A simple alternating current generator is driven by the machine and the current carried to a magnet placed on the bridge of the comb, which is thus made to vibrate in correspondence with the frequency of the current. All the springs are thus made to quiver slightly at their lower ends, and that particular spring whose natural period of vibration is most nearly in unison with the actuating impulses will be thrown into very strong vibration, and when these vibrations are exactly in synchronism with the natural period of a spring the amplitude will reach its maximum.

For indicating the speed of electrical machines, this invention is excellent. It can be used for paralleling alternators and polyphase generators, as a phase indicator, and for the determination of the slip of an induction motor. It also permits of the observation and supervision at one place of the running of any number of machines, and gives a centralization of management in a very efficient way.

The report concludes with the recommendation to the inventor of the John Scott Legacy Premium and Medal. *(Sub-Committee:*—William H. Thorne, Chairman; Jacob Y. McConnell and Richard L. Binder.)

The following report passed first reading:—

(No. 2405.) *The Contributions of the Baldwin Locomotive Works, of Philadelphia, Pa., to the Evolution of the American Locomotive.*

NEW BUSINESS.

(No. 2382.) *Etch-Powdering Machine.* Louis E. Levy, Philadelphia, Pa.

Under reconsideration proceedings the report on this case was amended by unanimous vote by substituting for the John Scott Legacy Premium and Medal the award of the Elliott Cresson Medal.

LOUIS E. LEVY, *Sec'y pro tem.*

(Stated meeting held April 3, 1907.)

DR. W. O. GRIGGS in the chair.

(No. 2405.) *The Contributions of the Baldwin Locomotive Works, of Philadelphia, Pa., to the Evolution of the American Locomotive.*

The report is reserved for publication in full.

The following report passed first reading:

(No.2387.) *Complete Expansion Gas Engine.* C. E. Sargent, of Chicago, Ill.

LOUIS E. LEVY, *Sec'y pro tem.*

(*Abstract of proceedings of the stated meeting held Wednesday, May 1, 1907.*)

DR. WM. O. GRIGGS in the chair.

The undermentioned reports were adopted:—

(No. 2363.) *Insulated Fireproof Wire.* J. Allen Heany, of York, Pa.

ABSTRACT:—This invention is protected by numerous Letters Patent granted to applicant and issued between dates of June 24, 1902, and March 15, 1904. These patents cover the machinery for applying the fireproof coating to the wire and the product. Prior to Mr. Heany's invention it has been shown to the satisfaction of the Committee that the only method of applying asbestos to a wire or other electrical conductor, consisted in spinning asbestos into a thread and then winding this thread spirally around the wire. The Committee refers in its report to several inventions of this character, viz:—that of Shuster (March, 1879.)and Splitdorf (June, 1888). and in commenting thereon, state in their report that this insulation has the serious disadvantage of opening and forming interstices between the windings of the thread when the wire is bent, which in turn causes short circuiting and thus, destruction of the wire in coils or armature windings, and leakage and danger to wood work and other inflammable material in buildings. The report notes other defects of this method of applying the insulation. but those above are the most conspicuous.

The Committee takes notice of a patent to Downes (February, 1895.) in which the inventor sought to overcome the defects of this insulation by raising a portion of the spiral thread of asbestos into a nap and then compressing the nap into the interstices; but this does not accomplish the desired purpose satisfactorily.

Mr. Heany departs from the path of his predecessors in abandoning the use of an asbestos thread and makes use of raw, flocculent asbestos, which has only been freed from impurities. By suitable mechanism Heany separates his asbestos into a filmy state and in this condition feeds it to the wire and forms thereon a thin homogeneous layer. Each fibre of the asbestos in this layer is spirally wound upon the wire or conductor and by an adhesive coating is firmly connected therewith. By this method the coating will not show interstices when the wire is sharply bent or twisted. The wire is subsequently treated with a waterproof composition. which forms a thin. pliable, enamel-like coating on the surface of the asbestos and renders it impervious to moisture.

Mr. Heany's method permits him to use the waste asbestos and asbestos of the lowest grade. being in strong contrast to the earlier methods of spinning a thread which required the use of the best material and longest fiber. This substantially reduces the cost of the material employed.

The report submits in the form of appended documents, a mass of evi-

dence in substantiation of the claims of the inventor, and finally concludes in the following terms that "Mr. Heany has done something which heretofore could not be accomplished manually or mechanically, and in view of the importance of the invention to the electrical industries, is entitled to the highest award of the Institute—the Elliott Cresson Medal." (*Sub-Committee,* Washington Deveraux, Chairman; Wm. McDevitt, Wilhelm Vogt and L. F. Rondinella.)

(No. 2387.) *Complete Expansion Gas Engine.* C. E. Sargent, of Chicago, Illinois.

Abstract:—The above invention is covered by a series of U. S. Letters Patent granted to applicant between Feb., 1900, and Feb., 1905. Copies of papers fully describing the invention in detail are submitted in the application. Blueprints showing efficiency tests are also filed with the papers.

The main feature in this engine lies in the method used for expanding the products of combustion to nearly atmospheric pressure. The cycle used is a modification of the Beau de Rochas or Otto Cycle. The admission of the explosive mixture is cut off at any desired point of the stroke, and thereby the compression is somewhat varied and the expansion considerably increased. The cut-off is controlled by a governor, thus being used to regulate the speed of the engine.

The desirability of a more complete expansion of the products of combustion has long been recognized, and various machines have been built to accomplish this purpose, such as Atkinson's cycle engine in England, the Niel, Charon and other engines in France. These, however, accomplished the results by means entirely different than those used by Sargent. The cycle he adopts is nevertheless not new, having been proposed by Koehler in 1895, and later practically applied by Koerting.

The governor, which is of the Rite's inertia type, controls all cams, advancing them more or less with reference to the crank. When the speed goes beyond normal, the cut-off, exhaust and exhaust closure as well as ignition are advanced. By this means some of the burned gases are imprisoned, thus causing a slight compression at the end of the scavenging stroke. The compression delays the admission, as the inlet poppet valve acts automatically by the suction produced by the piston as soon as the pressure within the cylinder drops below air pressure. Thus with light loads the admission is less from two causes, 1st, by the later admission; and 2nd, by the earlier cut-off. The imprisoned burned gases cause a more dilute mixture of the fresh charge and a higher compression. The ignition occurring earlier allows a longer time for the combustion of the poorer mixture and insures a high pressure at the early part of the power stroke.

Although the hit and miss principle of governing gas engines gives good economical results, it gives poor speed regulation. The form of governing adopted by Sargent gives a close speed regulation, and at the same time permits a great range of load variation and cut-off without appreciable loss in efficiency.

The greater expansion of the products of combustion reduces the ex-

haust temperature from the usual 1000° F. or more to the neighborhood of 400° F., making the average temperature existing in the cylinder much lower than in the gas engines of the usual type. This enables Mr. Sargent to construct his machine in the form of a double-acting tandem engine, and to obtain an impulse at each stroke of the engine.

The arrangement of the combined inlet and exhaust valve is somewhat on the order of that built by Fielding and Platt, and differs from it mainly in making exhaust valve a piston valve. This piston valve is ingeniously arranged so that it also acts as a cut-off valve, and furthermore, by being revolved can vary the mixture to suit the gas. By means of an ingeniously arranged dash-pot, the poppet valve is forced open, giving free admission to the charge.

Another simple and ingenious arrangement is the use of the spiral gears which drive the cam shaft, or an oil pump serving to distribute oil to all bearings.

It is the opinion of the Committee, that in the development of this engine a great deal of thoroughly scientific thought has been expended, and considerable ingenuity demonstrated by the inventor. He has produced an engine which in its nature should give high economy and close regulation, and has contributed to the advancement in the art of building internal combustion engines. The Committee therefore recommends the award of the John Scott Legacy Premium and Medal. (*Sub-Committee*, Arthur Falkenan, Chairman; Kern Dodge, Chas. Day and Chas. E. Ronaldson.)

(No. 2406.) *Machine for the Transmission of Power and Device for Hoisting Purposes.* Fred. G. Harbord, of Philadelphia, Pa.

This report was made advisory and adopted.

NEW BUSINESS.

A motion, duly seconded, was made to reconsider the Committee's action on Townsend's Thermometer Support. Under the rules, this was laid over for one month, or, until the next stated meeting.

Wm. H. Wahl, *Secretary.*

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